

DEPARTMENT OF HEALTH AND SOCIAL SECURITY  
SCOTTISH HOME AND HEALTH DEPARTMENT  
MINISTRY OF HEALTH AND SOCIAL SERVICES  
NORTHERN IRELAND  
WELSH OFFICE

# **Code of Practice for the Protection of Persons against Ionizing Radiations arising from Medical and Dental Use**

**LONDON**  
**HER MAJESTY'S STATIONERY OFFICE**  
**60p**



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## PREFACE

This Code is a revision of the Code prepared by the Standing Advisory Committee set up to advise Ministers under the Radioactive Substances Act 1948<sup>1</sup>. The Code was first published in 1957 and revised in 1964.

This revised Code applies to the use of ionizing radiations arising from all forms of medical and dental practice and from allied research involving human subjects. Where research procedures are not covered by the present Code reference should be made to the Code of Practice for the Protection of Persons exposed to Ionising Radiations in Research and Teaching<sup>46</sup> which has been designed to harmonize with it.

Although the arrangements recommended relate primarily to institutions they should be applied, as far as practicable, by all medical and dental practitioners.

As before, the policy pursued by the Committee has been to set out the basic principles of radiation control and to give general guidance on good practice.

The Code has been drawn up in the light of the recommendations of the International Commission on Radiological Protection and of the views of the Medical Research Council's Committee on Protection against Ionizing Radiations.

Technical information which will assist in the implementation of this Code is given in the Handbook of Radiological Protection, Part 1: Data<sup>45</sup>.



## MEMBERS OF THE RADIOACTIVE SUBSTANCES ADVISORY COMMITTEE

Professor Sir Brian Windeyer, M.B., B.S., F.R.C.P., F.R.C.S.,  
F.R.C.A. (Hon.), D.M.R.E., F.F.R.

G. M. Ardran, M.A., M.D., M.B., Ch.B., M.R.C.P., D.M.R.,  
F.F.R.

R. J. Callow, E.R.D., B.Sc.

J. V. Dunworth, C.B., C.B.E., M.A., Ph.D., C.Eng., F.I.E.E.,  
F.Inst.P.

Professor K. G. Emeleus, C.B.E., M.A., Ph.D., D.Sc., M.R.I.A.

Sir Frederick Hayday, C.B.E.

Professor L. F. Lamerton, D.Sc., Ph.D., F.Inst.P.

J. F. Loutit, C.B.E., M.A., D.M., F.R.C.P., F.R.S.

A. S. McLean, M.B., Ch.B., D.I.H.

Professor W. V. Mayneord, C.B.E., D.Sc., F.R.S.

Professor C. W. Miller, D.Sc., F.Inst.P.

Professor F. W. Spiers, C.B.E., D.Sc., Ph.D., F.Inst.P.

A. C. Stevenson, M.A., B.Sc., M.D., Ch.B., F.R.C.P., L.R.C.S.,  
L.R.F.P.S.

R. C. Tudway, M.B., B.S., B.Sc., D.M.R., F.F.R.

H. W. Wilson, B.Sc., Ph.D.

### *Joint Secretaries*

W. Binks, C.B.E., M.Sc., F.Inst.P. (to July 1969)

E. E. Smith, B.Sc., M.Inst.P. (from July 1969)

J. I. Jones, M.A., LL.B. (to May 1970)

G. F. Hawker, T.D., B.Sc. (Eng.), Barrister, (from May 1970)

### *Assessors*

H. R. Barnell, M.A., Ph.D., B.Sc., M.I.Biol.

E. A. B. Birse, O.B.E., B.Sc., Ph.D., F.R.I.C.

J. C. Cotterill, M.A., L.R.I.C., A.M.C.T.

B. H. Harvey, M.A., M.Sc., F.S.A.

A. W. Kenny, M.A., B.Sc., F.R.I.C.

E. A. Lennon, M.B., B.S., M.C.R.A., F.F.R.

## MEMBERS OF THE PANEL RESPONSIBLE FOR THE PREPARATION OF THE CODE OF PRACTICE

Professor Sir Brian Windeyer, M.B., B.S., F.R.C.P., F.R.C.S., F.R.C.A. (Hon.), D.M.R.E., F.F.R.  
G. M. Ardran, M.A., M.D., Ch.B., M.R.C.P., D.M.R., F.F.R.  
R. K. Christy, C.B., B.Sc., A.R.I.C.  
J. G. L. Cole, M.B., Ch.B., L.R.C.P., M.R.C.S., D.M.R.D., D.M.R.  
R. E. Ellis, B.Sc., Ph.D.  
B. H. Harvey, M.A., M.Sc., F.S.A.  
A. W. Kenny, M.A., B.Sc., F.R.I.C.  
T. Lodge, M.B., Ch.B., F.R.C.P., F.R.C.S., D.M.R., F.F.R.  
W. G. Marley, O.B.E., M.Sc., Ph.D., F.Inst.P.  
H. Miller, M.A., Ph.D., F.Inst.P.  
Professor J. E. Roberts, D.Sc., F.Inst.P.  
Professor E. Samuel, B.Sc., M.D., B.S., F.R.C.P., F.R.C.S., D.M.R.E., F.F.R.  
E. E. Smith, B.Sc., M.Inst.P.  
N. G. Trott, B.Sc., Ph.D., F.Inst.P.  
R. C. Tudway, M.B., B.S., B.Sc., D.M.R., F.F.R.

### *Secretaries*

W. Binks, C.B.E., M.Sc., F.Inst.P. (to July 1969)  
E. E. Smith, B.Sc., M.Inst.P. (from July 1969)  
R. P. S. Hughes (to March 1969)  
E. L. McMillan, C.B.E., A.F.C. (from March 1969)

### *Additional Members of Drafting Groups*

B. E. Godfrey, M.Sc., M.Inst.P.  
\*B. E. Jones, B.Sc., F.Inst.P.  
E. A. Lennon, M.B., B.S., M.C.R.A., F.F.R.  
F. Morley, B.Sc., M.Inst.P.  
M. C. O'Riordan, B.Sc.  
S. K. Stephenson, B.Sc., M.Inst.P.  
E. J. Wilson, B.Sc., Ph.D., F.R.I.C.

\* Deceased

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## NOTE

In this Code 'must' indicates an essential requirement, 'should' a desirable requirement.

Cases may arise where a departure from a 'must' requirement is expedient, yet would not jeopardize the interests of radiological protection. Such departures are only permitted when specifically authorized by the controlling authority in consultation with the radiological safety committee.

Specialized terms are defined in Appendix M.

Publications referred to in the text are numbered to accord with Appendix O.

# 1 SCOPE OF THE CODE

## 1.1 Establishments

**1.1.1** This Code applies to the use of ionizing radiations arising from medical and dental practice and from allied research involving human subjects. It does not deal with other uses of ionizing radiations, in, for example, Medical Schools and Colleges or in Medical Research Council Units, which are covered by other codes such as the Code of Practice for the Protection of Persons exposed to Ionizing Radiations in Research and Teaching<sup>46</sup>.

## 1.2 Persons

**1.2.1** The Code applies to all persons who may be exposed to ionizing radiations arising from medical and dental practice and allied research. For the purposes of the Code they are divided into the following categories:

- i Persons who may be exposed in the course of their work (i.e. all workers who are on the premises of an establishment for any reason connected with their work, including staff, temporary and visiting staff, and students). Persons so exposed are termed 'occupationally exposed persons' and for administrative purposes are divided into the following two groups, the distinction between them being based on the degree of likelihood that a certain dose will be exceeded.
  - a Designated persons. These are persons whose work involves exposure to ionizing radiations to such an extent that the resulting annual doses might exceed three-tenths of the annual maximum permissible doses listed in Table B1. Persons in this category must be subject to special medical supervision and individual monitoring (see Sections 2.1.9, 2.3, and 2.4).
  - b Other persons. These are persons whose exposure to radiation is such that the resulting annual doses are most unlikely to exceed three-tenths of the annual maximum permissible doses. Individual monitoring and special medical supervision will not be required for persons in this category. However, where such persons perform all or part of their work in the vicinity of radiation equipment the working environment must be monitored (see Section 2.5).
- ii Patients. These are persons undergoing examination or treatment by ionizing radiations.
- iii Members of the public, including patients not undergoing examination or treatment by ionizing radiations.

iv Persons subjected to investigations for purposes of research which involve exposure to ionizing radiations.

In Appendix B are listed maximum permissible doses for persons in category i. and 'dose limits' for members of the public (category iii.). While maximum permissible doses are firm limits and the doses to designated persons must be individually monitored and controlled (see Section 2.3 and 2.4), the purpose of the concept of dose limitation for members of the public is to provide standards for the design and operation of radiation sources so that it is unlikely that such members will receive more than a specified dose (see Table B2).

## 2 GENERAL MEASURES FOR RADIOLOGICAL PROTECTION

### 2.1 Responsibility for the organization of radiological protection.

2.1.1 The ultimate responsibility for protection measures in a hospital or other place in which this Code applies, and where human subjects are irradiated other than as workers, lies with the Controlling Authority. The Authority is responsible for the protection of all workers (whether or not they are employed by the Authority), patients, and members of the public on their premises. To assist in the discharge of this duty the Controlling Authority must set up a Radiological Safety Committee; one Radiological Safety Committee may be nominated to serve more than one Controlling Authority. The Committee must consider the reports of the Radiological Protection Adviser, must inform the Controlling Authority at least every 12 months of the state of protection arrangements and, where any specific problems arise, must advise the Controlling Authority on any further measures which may appear necessary. In the case of a health centre under the control of a Local Authority there should be a consultant radiologist on the Radiological Safety Committee set up by that body.

2.1.2 In every department where radiation is used the responsibility for ensuring that the Code of Practice is observed must lie with the Head of the Department, in collaboration with the radiological safety organization of the institution, except that where X-ray equipment is used outside the Radiological Department the overall responsibility for observance of the Code lies with the Head of the Radiological Department in collaboration with the radiological safety organization. Where radioactive substances are applied to patients, e.g. in wards and operating theatres, radiological safety measures are the responsibility of the clinician in charge of the patient in collaboration with the radiological safety organization of the institution.

2.1.3 Each Controlling Authority must be served by an appropriately qualified and experienced physicist to act as Radiological Protection Adviser, who may be appointed by the Controlling Authority, Controlling Authorities or, where appropriate, by a Regional Hospital Board. He should regularly visit the hospitals and departments, to which he has been nominated, to review, in consultation with the Heads of Departments, the protection measures laid down.

2.1.4 For every department in which radiation is used, the Controlling Authority must appoint a competent person as Radiological

Safety Officer to ensure that protection measures are carried out. The Head of the Department must be consulted about the appointment which should, wherever possible, be from among the full-time employees in the department. Where X-ray equipment is used outside that department, protection measures are the responsibility of the Radiological Safety Officer appointed to the Radiological Department. The Controlling Authority must ensure that the Radiological Safety Officer receives any training needed to fit him for his duties.

**2.1.5** Each Controlling authority must appoint a Supervisory Medical Officer who will be responsible for the medical supervision of the staff concerned in the hospitals under its administrative control. Such staff will include:

- i All persons who are 'designated persons' or potential 'designated persons'.
- ii Other staff who may have been significantly irradiated as a result of accidental exposure to ionizing radiations.

**2.1.6** An example of the administrative organization suitable in National Health Service Hospitals is shown in Appendix A.

**2.1.7** Each Radiological Safety Officer must regularly report details of the doses received by the staff to the Head of Department or clinician responsible for observance of the Code under Section 2.1.2. The Head of the Department or clinician must then report to the Radiological Safety Committee. A copy of the report should be sent to the Radiological Protection Adviser unless the Adviser is in a position (e.g. through being associated with the film badge service or other individual monitoring service) to receive the information directly. Additionally the Radiological Safety Officer and the Head of Department or clinician must make special reports when circumstances warrant this course. The Head of the Department or clinician must report to the Radiological Protection Adviser when any change of equipment, usage, or environment occurs which may affect the radiological safety of the department. The Radiological Safety Officer must have discretion to approach the Radiological Protection Adviser direct if he considers this necessary in the interests of safety. In such cases he must send a copy of any report to the Head of Department or the clinician concerned. The Adviser must inform the Controlling Authority, the Radiological Safety Committee, and the Head of Department or clinician concerned of any reports which indicate unsatisfactory conditions and must set out the measures to be adopted to remedy them. The Controlling Authority, in consultation with the Radiological Safety Committee and the Head of the Department or the clinician concerned, must decide whether any action, including the suspension of operations, is necessary.

**2.1.8** The Controlling Authority must determine, in respect of all

persons exposed in the course of their work (see Section 1.2.1.i), whether or not they shall be identified as 'designated persons' as defined in Section 1.2.1 i.a. In Section 2.1.9 the types of employment in which persons must normally be designated are listed. Other persons must be designated if there is a reasonable possibility of their receiving doses exceeding three-tenths of the relevant maximum permissible doses given in Appendix B. The Controlling Authority must keep a person's designation under review (see Sections 2.1.9 and 2.3).

**2.1.9 All persons employed in:**

- i Work associated with sealed or unsealed radioactive substances or machines or apparatus emitting ionizing radiations or immediately ancillary work or
- ii The cleaning of active areas or the cleaning of plant, apparatus, equipment, materials or articles which are contaminated or are liable to have been contaminated with radioactive substances;

must be identified as 'designated persons' unless the Controlling Authority is satisfied, on the advice of the Radiological Safety Committee, that the operating and working conditions and the system of control and instruction are such that the radiation doses received by the staff concerned are most unlikely to exceed three-tenths of the annual maximum permissible doses (see Appendix B), that there is adequate protection against external contamination from any unsealed radioactive substances, and that there is sufficient monitoring of the working environment.

**2.1.10** Every effort must be made to keep exposure of workers as low as is reasonably practicable. Persons must not be exposed to ionizing radiations to a greater extent than is necessary, and in no case in excess of the levels laid down in Appendix B unless this is justified by the existence of an emergency (see note e of Table B1).

**2.1.11** The Controlling Authority must supervise with particular care the conditions of work of persons under the age of 18 years (see footnote to Table B1). Persons under the age of 16 years must not in any circumstances be allowed to engage in work which would require them to be designated persons.

**2.1.12** Each Controlling Authority must ensure that all persons referred to in Section 1.2.1.i are adequately instructed about the hazards they may meet and the precautions to be observed. In hospitals, Controlling Authorities should be advised in this respect by the Radiological Safety Committee. All authorized visitors to areas in which ionizing radiations are present must be informed, as necessary, of the precautions to be observed.

**2.1.13** Each Controlling Authority must arrange for local rules, consistent with the principles of this Code, to be drawn up in consultation with the Radiological Safety Committee. The rules must set out clearly and precisely the procedure in force in each establishment and the names and duties of the persons such as the Radiological Protection Adviser, the Supervisory Medical Officer, and the Radiological Safety Officer who are allocated responsibilities for health and safety. Any such person must be given a clear written statement of his duties.

**2.1.14** It must be impressed on every individual designated person that he has a duty to protect himself and others from any hazard arising from his work.

**2.1.15** Every member of the staff and every designated person to whom this Code applies must be familiar with the responsibilities and precautions imposed on him by the Code and by the local rules. The Controlling Authority must ensure that he reads either the relevant sections of the Code and of the local rules or a suitable statement which explains clearly his own responsibilities. He must sign a statement that he is aware of and understands these responsibilities.

## **2.2 Records**

**2.2.1** The Controlling Authority must arrange (in accordance with the paragraphs set out below) for the following records to be kept:

Cases of over-exposure (see Section 2.3.7).

Radiation dose record (see Sections 2.3.7, 2.4.6, 2.4.7, 2.4.10, and 6.8.4).

Medical record (see Section 2.3.9).

Transfer record (see Sections 2.4.8, 2.4.9, 2.4.10, and Appendix E).

Cases of contamination of skin, hair, and clothing (see Section 2.4.11).

Monitoring of working areas (see Sections 2.5.1, and 6.7.1).

Calibration of monitoring instruments (see Section 2.6.2).

Alteration of output or quality of radiation as a result of modification or maintenance of apparatus (see Sections 3.10.9 and 4.1.8).

Tests of protective gloves and aprons (see Section 3.16.4).

Calibration of dose-rate meters used for evaluating treatment doses (see Sections 4.2.7 and 4.3.5).

Leakage tests (see Sections 4.4.7, 4.5.8, 4.6.4, 5.1.8, 9.2.15 and 9.2.20).

Record of administration of permanent implants (see Section 5.1.3).

Central record of all sealed sources issued from and returned to the main store (see Sections 5.1.3 and 9.2.16).

Register of stock of all sealed sources having half-life greater than a few days (see Sections 5.1.8, 9.2.15 and 9.2.20).

Record of administration of unsealed radioactive substances (see Section 6.1.5).

Investigation of emergencies (see Section 6.9.10).

Record of radiotherapy (see Section 7.5.1).

Central record of all unsealed radioactive substances issued from and returned to the main store (see Section 9.2.27).

Record of stocks of unsealed radioactive substances (see Section 9.2.29).

Disposal of radioactive waste (see Sections 9.2.29 and 10.3.2).

## 2.3 Medical examinations

### 2.3.1 The main purposes of medical examinations are:

- i To assess the fitness on medical grounds of a person to perform his duties without danger to himself or to others.
- ii To establish a record of the condition of the individual to serve as a base-line against which any subsequent change can be evaluated.
- iii To assess continuing fitness and to detect any deterioration in health.

### 2.3.2 For any medical examination, the Supervisory Medical Officer may at his discretion request a 'full blood examination' or any other special examination (including X-ray examination, ophthalmological examination, and examination of the skin and nails).

### 2.3.3 A 'full blood examination' should either consist of or include:

- i In the case of red blood cells, a measurement of the packed cell volume.
- ii In the case of white blood cells, an estimate of the number present per cubic millimetre of whole blood.
- iii A differential white cell count.
- iv A search for abnormal cells and a description of any seen.
- v An estimation of the haemoglobin in grammes per 100 millilitres of whole blood.

### 2.3.4 A person must not be employed as a 'designated person' unless within the period of 4 months immediately preceding first employment as a 'designated person' he has been subjected to a general medical examination including a 'full blood examination'. (The expression 'first employment' means first employment as a 'designated person', and also re-employment as such following any cessation of such employment for a period of 12 months or more).

**2.3.5** Every 'designated person' should be re-examined annually to check continued fitness for such work, unless it is clear from individual monitoring that he is consistently receiving less than three-tenths of the relevant annual maximum permissible dose (see Section 1.2.1).

**2.3.6** Where there is reason to think that any 'designated person' has received a radiation dose or dose commitment in excess of the maximum permissible doses for occupationally exposed persons (see Table B1) or that any person in the category of 'other persons' has received a dose or dose commitment in excess of three-tenths of the maximum permissible doses for occupationally exposed persons, or that any occupationally exposed person has excessively contaminated any surface of his body (see Table D1) an enquiry into the circumstances must be made.

**2.3.7** Where any person has received a dose in excess of those described in Section 2.3.6, the Supervisory Medical Officer must decide whether or not:

- i To carry out a medical examination of the person concerned, or such other investigation as may be indicated.
- ii To arrange remedial treatment.
- iii To make recommendations on the amount of subsequent exposure of that person or on the suspension of the person from employment as a designated person. (If the dose received exceeds that permitted for a planned special exposure or if, in the case of the gonads, red bone-marrow and whole body, the sum of the dose from over-exposure and the total occupational dose received up to the time of the accident exceeds  $5(N-18)$  rems, where N is the person's age in years (see Appendix B), the Supervisory Medical Officer, having also taken into account in making these recommendations the worker's general health, age, special skills, and social and economic responsibilities, must consider whether the worker may still be allowed to continue routine work or whether he should be suspended for a period from work under conditions related to designated persons).

Where necessary, a special entry approved by the Controlling Authority must be made in the radiation dose record kept in accordance with Section 2.4.6. In the case of a person who is not designated a radiation dose record must be specially created for this purpose.

**2.3.8** Where appropriate a report should be submitted to either the Department of Health and Social Security in accordance with HM(55)66<sup>50</sup> and HM(67)31<sup>51</sup>, the Scottish Home and Health

Department, or the Ministry of Health and Social Services, Northern Ireland in accordance with HMC 98/54<sup>52</sup>, HMC 8/57<sup>53</sup>, and HMC 131/68<sup>54</sup>.

**2.3.9** To enable the health of designated persons to be kept under progressive review, the Controlling Authority must arrange for records to be kept of all medical examinations including blood examinations and such other investigation as is necessary. These records must be retained for 30 years after the last entry. (See also Section 2.4.10). The Controlling Authority may arrange for the records of persons no longer employed by it to be retained on its behalf by another body, e.g. in a central registry.

#### **2.4 Individual monitoring**

**2.4.1** Where a designated person is exposed to significant irradiation from external sources the dose of ionizing radiations received must be systematically checked. Normally it is sufficient if the person wears one or more dosimeters on an appropriate part or parts of his body during the whole time he is liable to be exposed to ionizing radiations. A single test with a dosimeter should not normally extend beyond 4 weeks. In some circumstances it may be necessary for the person to wear a pocket ionization chamber which would give immediate readings of the dose received. Radiations such as low energy beta-rays which cannot easily be measured by individual dosimeters should be checked by site monitoring or other procedures.

**2.4.2** An individual dosimeter should normally be worn on the trunk at chest or waist level underneath the protective apron (see Section 3.16) if one is worn. Where there is any reason to suspect that doses to unprotected parts may approach the maximum permissible doses (see Appendix B), the Radiological Protection Adviser must carry out a radiation survey of the department and arrange for the wearing of additional dosimeters if he considers this to be necessary. If there is a significant dose registered on a monitoring device worn underneath an apron the dose to unprotected parts may be excessive (see Sections 3.16.1, 2, and 3).

**2.4.3** Where workers may be present in the vicinity of sources of radiation but the Controlling Authority is satisfied after applying the criteria set out in Section 2.1.9 that there is no need for them to be designated, the working environment must be monitored periodically in accordance with the advice of the Radiological Protection Adviser. The most economical means of doing this would usually be for the workers concerned to wear film badges or other monitoring devices.

**2.4.4** The doses received from internal radiation arising from the intake of radioactive substances into the body by inhalation or ingestion, by absorption through the skin, or by entry through

wounds, must be evaluated where necessary. Guidance on the action to be taken is given in the H.P.A. Report Series No. 2<sup>63</sup>; advice about dose evaluation can also be obtained from the National Radiological Protection Board. (See also Section 2.3.6).

**2.4.5** In addition to individual monitoring of external radiation by film badges or other measuring devices, where appropriate, the levels of contamination of the skin, hair, and clothing must be checked regularly to ensure that any excessive contamination is detected without delay.

**2.4.6** The Controlling Authority must ensure that a separate radiation dose record is maintained for each designated person. The record should show any dose received as a result of previous work with ionizing radiations and the doses received in each calendar quarter and in each year. When doses received from any radioactive substances deposited within the body have been evaluated these should be noted on the record.

**2.4.7** The radiation dose record provides a continuous check on the extent of the radiation doses received and acts as a useful pointer to the efficacy of the safety measures in force. It must be available for inspection by the Supervisory Medical Officer, the Radiological Protection Adviser, the Head of the Department, and the individual concerned. If the records are kept by a person other than a Radiological Safety Officer, the latter must have a record of the doses received by each person for whom he has responsibility.

**2.4.8** A summary of the radiation dose record (known as a 'transfer record') must be issued to each designated person as soon as possible after he finally leaves the establishment so that he can produce it on taking up work involving exposure to ionizing radiation elsewhere. A specimen form of transfer record is shown in Appendix E.

**2.4.9** When the Controlling Authority is aware that a designated person has worked elsewhere with ionizing radiations it must obtain a transfer record for him.

**2.4.10** The radiation dose records and the transfer records relating to previous exposure must be retained for a period of 30 years after the last entry as they may be of considerable value in considering long-term effects of radiation on the individual. The Controlling Authority may arrange for the records of persons no longer employed by it to be retained on its behalf by another body, e.g. in a central registry.

**2.4.11** Where the contamination of skin, hair, and clothing cannot be reduced by first-aid measures to a level below that given in Table D1, a separate record of this event should be attached to the medical

record and retained for two years. The record should indicate the cause of the contamination, the action taken to deal with it, and the length of time during which the excess contamination lasted.

## 2.5 Environmental monitoring

**2.5.1** The working environment must be surveyed at regular intervals to determine the following:

- i The levels of external radiation.
- ii The levels of radioactive contamination of surfaces in areas where unsealed radioactive substances are used, and of the surfaces of personal protective equipment.
- iii The concentration of radioactive substances in the air if this is advised by the Radiological Protection Adviser (see Section 6.7.9).

Monitoring results must be properly recorded for future reference.

**2.5.2** A radiation survey must be made of any new or modified department. Such surveys must be made under the guidance of the Radiological Protection Adviser. It should be appreciated, however, that for work with unsealed radioactive substances protection is as much a matter of procedure as of design. A 'modified department' means one in which the original protection may no longer be adequate for any one of the following reasons:

- i The radiation output of radiological equipment has been increased.
- ii The radiation output of a sealed source has been increased.
- iii The activity of an unsealed radioactive substance has been increased.
- iv The radionuclide used as an unsealed substance has been changed.
- v The position of a radiation source has been changed.
- vi The techniques have been modified.

If the radiation survey indicates that persons may under normal working conditions receive doses in excess of the levels reasonable in the circumstances for the particular type of work, the Radiological Protection Adviser must indicate the measures to be adopted to rectify the situation. The installation involved should not be used until the protection is satisfactory.

**2.5.3** A radiation survey must also be carried out if individual monitoring indicates that the doses received by designated persons exceed or are likely to exceed the quarterly maximum permissible levels and if enquiries have failed to reveal the cause. When the cause has been determined (e.g. defective equipment, inadequate protection afforded by screens and walls, wrong technique, or insufficient staff)

the Radiological Protection Adviser must indicate the measures to be adopted to rectify the situation. Appropriate action must then be taken to reduce the hazard.

## **2.6 Monitoring instruments**

**2.6.1** The Controlling Authority in consultation with the Radiological Protection Adviser must make available efficient monitoring instruments of types suitable for environmental surveys and assessment of contamination. Where possible the user should be able to make a quick and simple check of the performance of the instruments.

**2.6.2** The Controlling Authority must ensure that the instruments are tested and calibrated by a suitably qualified person when they are first taken into use and that the calibration is verified at least annually. The instruments must be properly maintained; after repair of any defect that could affect their accuracy, they must be retested and their calibration verified. Records should be maintained of the dates and results of all tests, calibrations, and calibration verifications and kept for 2 years after the last entry.

## **2.7 Planning of radiological departments**

**2.7.1** When planning a new radiological department or modifying an existing one, authoritative advice (e.g. from the National Radiological Protection Board) should be obtained about the suitability of the location, design, and construction of the premises and equipment, and about the arrangements for the storage of radioactive substances and for the disposal of radioactive waste. (A 'modified department' is defined in Section 2.5.2).

**2.7.2** When planning a new radiological installation, account should be taken of the expected work-load of any equipment, the use factors of the barriers, and the occupancy factors of the adjacent areas. Allowance should be made for possible future increases in these factors, for changes in the outputs or positions of radioactive sources, and for future modifications in technique.

## **2.8 Fire emergencies involving radioactive substances**

**2.8.1** By arrangement with the Chief Fire Officer\* the Local Fire Brigade should be given the opportunity to visit the establishment to obtain information about the layout of the premises and about warning measures and symbols etc. The Chief Fire Officer should also be consulted about first aid and fire fighting equipment suitable for the risk in any radiation area.

**2.8.2** There should be readily available an up-to-date list of all places in the establishment where there are radiation hazards showing

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\*In Scotland the Firemaster.

the exact location of and the means of access to all rooms likely to contain radioactive substances. The Chief Fire Officer should be given a copy of this list.

**2.8.3** Arising out of consultations with the Chief Fire Officer, local rules must be drawn up which detail the procedure to be followed in the event of a fire involving radioactive substances. These rules, which must be read by all persons who may be concerned, must include a list of those uses of radioactive substances which involve such activities as to be particularly hazardous in the event of fire, and reference should be made to the dangers arising from inhalation and contamination in the vicinity of the fire to those engaged in fire fighting and to those entering the area after the fire.

### 3 DIAGNOSTIC USE OF X-RAYS

#### 3.1 Principles

**3.1.1** Protection in diagnostic radiology should be based on the following principles:

- i That the irradiation of the patient during X-ray examination must be no greater than is necessary to produce a satisfactory result and that care should be taken to reduce to a minimum the irradiation of particularly sensitive tissues such as the bone marrow and gonads.
- ii That all provisions for absorbing primary and secondary radiation should be as close as possible to the apparatus or patient.
- iii That X-rays should be used only when there is adequate protection for all persons in all surrounding areas.

**3.1.2** Attention is drawn to Section 7 of this Code which covers those aspects of protection of the patient which are of particular concern to the administrator and to the clinician requesting an examination.

#### 3.2 Structural aspects

**3.2.1** To afford adequate protection to persons working in X-ray rooms, the following measures are required:

- i All X-ray rooms must have sufficient space to provide safe accommodation for all persons who are in the room.
- ii Protected areas must be provided for personnel at all control tables such that no significant radiation dose would be received even by a person not wearing protective clothing. Protection for such an area should normally be by means of protective cubicles or protective panels.
- iii An X-ray room should not be used for more than one radiological procedure at a time unless this is the only practicable means of conducting the required number of X-ray examinations. When a room is so used there must be adequate protective measures to ensure that there is no significant additional exposure, either of one patient from radiography of the other, or of staff from examinations for which they are not responsible. (See also Section 3.10.6).
- iv X-ray rooms must be marked with the recognized symbol, together with any appropriate words which may be required by local rules, to indicate the presence of ionizing radiations (see Appendix F).

**3.2.2** Adequate protection must be provided for persons in all occupied areas adjacent to X-ray rooms. This can be done most efficiently and economically by the following:

- i Where practicable, pointing the useful beam away from adjacent occupied areas.
- ii Absorbing the useful beam and scattered radiation as close as possible to the film or fluorescent screen and patient.
- iii Where necessary, applying protective material to the floor, ceiling and walls, including windows and doors.

### **3.3 General procedures**

**3.3.1** In hospitals all X-ray examinations, except mass miniature radiography and dental radiography, should preferably be carried out in the diagnostic radiological department, unless the condition of the patient makes it advisable for the examination to be carried out in a ward or in an operating theatre where proper facilities exist. Access doors to all radiological departments should be wide enough to allow beds from the wards to pass through and equipment should be so arranged that the patients are subjected to the minimum of disturbance.

**3.3.2** Only those persons whose presence is essential should remain in an X-ray room when radiological examinations are being carried out.

**3.3.3** The operator must stand as far as practicable from the useful beam and must not be exposed to it unless it is attenuated so as to reduce the radiation to levels which are not significant.

**3.3.4** Whenever possible, staff (including any students who may be present) should remain behind protective panels during all types of radiographic or fluoroscopic examinations. If this cannot be done protective clothing must be worn and staff should as far as reasonably possible occupy the areas of the room where the radiation levels are lowest. This is particularly important in certain elaborate investigations such as cardiological procedures where there may be a large number of people in the room.

**3.3.5** Support for children or weak or anaesthetized patients is sometimes needed in wards and X-ray departments and, where practicable, mechanical devices to ensure immobilization should be used. Where these devices cannot be used great care should be taken to ensure that one person does not regularly support these patients since this is a hazardous practice. Child patients should, if possible, be held only by their parents or other accompanying adults. The person supporting a patient who is being X-rayed must wear a protective apron and be as far outside the useful beam as is practicable.

Protective gloves should be worn if the hands are likely at any time to be close to the useful beam. If there is a serious likelihood that the person supporting the patient will receive a significant dose, or if the person is a hospital employee or other person who may possibly be asked to give support on repeated occasions and is not a designated person, he must be provided with a film badge or pocket dosimeter for the occasion. The circumstances in which an individual monitoring device must be worn must be defined in the local rules or be agreed with the Radiological Safety Officer. On all occasions when a significant dose is recorded during these procedures a report must be made to the Radiological Safety Officer.

**3.3.6** Radiographers should ensure that patients, staff, and escorts are properly instructed in their respective roles before X-ray examinations are made.

**3.3.7** The beam should not be directed towards parts of the body other than those to be examined, especially the gonads, unless this is essential to the conduct of the examination. This should be borne in mind particularly in examination of the limbs, especially of the hands with the patient in the sitting position.

**3.3.8** For young persons and persons of reproductive capacity adequate gonad shields must always be used in examinations which are likely to give a high gonad dose, unless these shields interfere with the proposed examination.

**3.3.9** In the examination of pregnant women, particular care must be taken to minimize irradiation of the foetus (see Section 7.3).

**3.3.10** Strict limitation of field size to the area necessary for the particular examination should be routinely practised. It is particularly important with children that the field should always be restricted to the essential area and should always be smaller than the film size.

**3.3.11** Careless methods with wide-open diaphragms will lead to unnecessary irradiation of the patient as well as to increased scattered radiation. The use of cones and collimators as recommended in this Code will largely eliminate one of the major sources of unnecessary radiation (see Section 3.11.1).

**3.3.12** To avoid accidental over-exposure of patients, there must be a rigid procedure in operating apparatus and each member of staff must be aware of this and must clearly understand the extent of his own responsibility. The procedure must include the checking of radiographic factors and operating conditions by the person responsible for making the exposure, on each occasion before an examination is made.

### **3.4 Radiographic procedures**

**3.4.1** The X-ray exposure should normally be controlled from the control panel, and the switch should be so situated that the operator cannot leave the protected area during the exposure. Local rules should be drawn up for any exceptions to this rule in the case of special techniques and special apparatus. In such cases staff must wear protective clothing if they are not behind protective panels.

**3.4.2** The operator should always have a clear view of the patient. If necessary, control cubicles and screens should have protective lead glass windows.

**3.4.3** The fastest films and intensifying screens consistent with satisfactory diagnostic results should be used.

### **3.5 Fluoroscopic procedures**

**3.5.1** The dose to patients and staff from fluoroscopic examinations is relatively very high. Fluoroscopy should not be undertaken if the same information can be obtained by radiography. Fluoroscopy should not be used for locating metallic foreign bodies at operations, as electronic metal locating equipment is now available.

**3.5.2** Where possible image-intensification should be used in order to reduce the dose received by the patient.

**3.5.3** All fluoroscopic examinations should be conducted as rapidly as possible with minimum dose-rates and apertures. Where image-intensification is not used, a guide to the factors used is that they should be of the order of 75 kV and 2 to 3 mA. There must be adequate dark adaptation so that there should be no need to exceed either 100 kV or 4 mA. Except when image-intensification is used dark adaptation will take not less than 10 minutes.

**3.5.4** The dose-rates and total doses delivered to patients during cinefluorography may be very high. The total number of frames exposed, the radiological factors and the field size should be kept to a minimum.

**3.5.5** During fluoroscopy with the patient in the erect position a radiographer or any other person who stands near the radiologist should ensure that in taking up such a position he is protected by the lead glass of the fluoroscopic screen or intensifier surround and by the protective apron suspended from it and that he is not directly exposed to scattered radiation from the patient, the dose-rate due to such scatter being highest to the side of the apparatus.

**3.5.6** During fluoroscopy, palpation with the hand, which should preferably be undertaken on the screen side of the patient, should be

reduced to a minimum. A protective glove (see Sections 3.16.1, 3.16.2, and 3.16.4) of appropriate lead equivalent thickness should always be worn during palpation.

**3.5.7** Foot, ankle, and shin exposure of staff during fluoroscopic procedures varies greatly with technique. Radiological Protection Advisers must ensure, by means of surveys and local rules as appropriate, that the doses received are within those shown in Table B1.

**3.5.8** In training establishments it is important to emphasize that fluoroscopy should be undertaken with as small a diaphragm opening as is practicable. An instrument for indicating the surface integral of exposure (the product of the exposure and the area in  $\text{Rcm}^2$ ) should be made available for this purpose.

### **3.6 Mass miniature radiographic procedures**

**3.6.1** In order to minimize any radiation hazard to the general public, persons awaiting their turn for examination must do so in an area which provides adequate protection.

**3.6.2** In mobile units for mass miniature radiography, the X-ray tube and patient must be so positioned and shielded that persons in the vicinity are afforded adequate protection.

**3.6.3** Mass miniature techniques should not be used for chest examinations of pregnant women. Full sized films with strict limitation of field size should be used for these examinations. If mass miniature techniques need to be used for children and for adults of short stature, particular care must be taken to exclude the gonads from the beam.

### **3.7 Dental radiographic procedures**

**3.7.1** Wherever possible the dental film should be fixed in position; otherwise it should be held by the patient or, exceptionally, by a person who is not a 'designated person' (as defined in Section 1.2.1). It must not be held by the dentist or members of his staff.

**3.7.2** The tube housing must not be held by hand during exposure.

**3.7.3** A field-defining spacer-cone (see Section 3.14.1) must be employed except when intra-oral X-ray tubes are being used. In tomography appropriate cones must be used.

**3.7.4** The operator must make certain that no part of his body is exposed to the useful beam and that the latter does not irradiate other persons in the vicinity.

### **3.8 Dental fluoroscopic procedures**

**3.8.1** The results obtained by intra-oral fluoroscopy do not justify its use. In view of the hazards of this technique it must be abandoned.

### **3.9 Precautions with mobile and portable equipment**

**3.9.1** The precautions already specified in Section 3.3 apply equally to mobile and portable X-ray apparatus and other forms of ionizing radiation used for radiographic purposes.

**3.9.2** When mobile or portable apparatus is used, the operator must make certain that no part of his body is exposed to the useful beam and should ensure that other persons in the vicinity of the patient are afforded adequate protection.

**3.9.3** Whenever possible light-beam diaphragms, or other beam-limiting devices, should be employed to reduce unnecessary irradiation of the patient concerned, as well as that of other individuals in the vicinity. The minimum focus skin distance should be 30 cm.

**3.9.4** Mobile and portable equipment unless properly designed for fluoroscopy with image intensification must not be used for fluoroscopy.

### **3.10 Equipment: general requirements**

**3.10.1** A diagnostic-type tube housing (see Appendix G) must be used.

**3.10.2** The total tube filtration, inherent plus added, for normal diagnostic work including dental radiography must be equivalent to not less than the following:

- i 1.5 mm of aluminium at voltages up to and including 70 kV.
- ii 2.0 mm of aluminium at voltages above 70 kV and up to and including 100 kV.
- iii 2.5 mm of aluminium at voltages above 100 kV.

In the case of tubes for general examinations which may be used for soft tissue procedures such as mammography, when the filter is removable there must be some permanent visible indication on the tube housing that the filter has been removed. Even when the main filter has been removed the total filtration must not be less than 0.5 mm equivalent of aluminium; this is particularly important in the case of beryllium window tubes, the inherent filtration of which is only equivalent to about 0.05 mm of aluminium.

**3.10.3** The maximum cross section of the useful beam from every diagnostic X-ray tube should be limited, if necessary by means of a stop fitted in the tube aperture, to the maximum required in practice for each particular tube. The stop, which should be located close to the tube window, should afford the same degree of protection as the tube housing.

**3.10.4** Apertures, cones, or diaphragms which serve to limit the useful beam should, as far as is practicable, afford the same degree of protection as the tube housing.

**3.10.5** Image intensifiers are essential in certain special procedures such as cardiac catheterization and cinefluorography (see Sections 3.5.2 and 3.5.3). The intensifier housing and supporting plates must provide shielding equivalent to at least 2 mm lead for 100 kV. From 100 to 150 kV an additional lead equivalent of 0.01 mm per kV is required.

**3.10.6** There must be a visible light on the control panel which is illuminated when the set is switched on and the filaments are alight, indicating that an exposure is being or is about to be made. When more than one patient may be examined at the same time in the same room or in adjacent rooms using several tubes but one generator, each tube must have a warning light which is clearly visible. Each light should be as close to its tube housing as practicable to indicate that the filament of that particular tube is switched on and that there is likely to be an X-ray exposure from it. The mechanism should be so constructed that if the warning system fails then X-rays will not be generated. The tube selector switch should be labelled with appropriate names, e.g. overcouch tube, chest-stand tube.

**3.10.7** When fluoroscopy is intended on certain tubes only, fluoroscopic switches (whether hand or foot operated) must be so connected that they cannot energize tubes intended for radiography only.

**3.10.8** All diagnostic equipment must have an exposure switch which has to be pressed throughout and a timer which will terminate the exposure after a pre-set time if the switch has not already been released. (See also Section 3.12.6).

**3.10.9** Any person who carries out any modification to, or maintenance of, any apparatus which might alter the output or quality of the radiation or the protection of the tube, must immediately attach to the apparatus an appropriate visible notification of such modification or maintenance and must, on each occasion, inform (in writing) the Radiological Safety Officer and the radiographer-in-charge; the latter must enter the details in a record book kept for the purpose.

### **3.11 Radiographic equipment**

**3.11.1** All X-ray apparatus must be equipped with properly aligned adjustable beam-limiting devices or cones to keep the useful beam within the limits of the X-ray film selected for each examination. (See also Sections 3.10.3 and 3.10.4). The film selected should be as small as possible consistent with the diagnostic requirements.

### **3.12 Fluoroscopic equipment**

**3.12.1** All tables and stands which are used for fluoroscopy must be provided with an adequate arrangement for protecting the operator

and his assistants against scattered radiation from the patient and from materials between the source and the patient. This may take the form of a protective apron which must be not less than 45 cm wide and 45 cm long and must be made of protective material having a lead equivalent of not less than 0.5 mm. The apron must be attached to the lower edge of the screen holder when the latter is vertical and to the operator's side of the screen holder when this is horizontal. Additional protective aprons or fixed shields should be attached to both sides of the table when the screen is horizontal and, if practicable, also to both sides of the stand when the screen is vertical. The beam-limiting device should extend as close as is possible to the back of the table or stand.

**3.12.2** The circuit on the primary side of the equipment must be so constructed that currents in the X-ray tube do not exceed 5 mA during fluoroscopy. A separate switch must be provided for cinefluoroscopy when the tube currents exceed 5 mA.

**3.12.3** The protective enclosure of the X-ray tube used for fluoroscopic examinations should be provided with an adjustable diaphragm system of such a design as will permit it to be completely closed. To prevent the lateral escape of radiation, the diaphragm system must be fitted within a protective enclosure. The material of the diaphragm should, as far as practicable, afford the same protection as the tube housing. The tube diaphragm and housing must be mounted in such a way that they will always move together.

**3.12.4** The tube aperture must be limited, preferably by automatic means, so that the useful beam is confined within the fluorescent area of the screen, whatever the distance of the tube from the fluorescent screen.

**3.12.5** Under the conditions that obtain in direct fluoroscopy, screen definition is not a limiting factor in the perception of the image and, therefore, high sensitivity fluorescent screens should be used. Old fluorescent screens which are found to be much less sensitive than new ones should be replaced. The protective glass should be replaced if its optical density has increased significantly due to discolouration caused by the irradiation.

**3.12.6** The fluoroscopic exposure must be under the control of a spring-biassed switch so that the exposure is automatically terminated when pressure is released. In addition, the circuit must incorporate a timing device with a maximum time range of not more than 10 minutes and arranged to terminate the exposure when the maximum time is reached. The timing device must be capable of being pre-set and must give an audible warning, visible warning, or both when the pre-set time has been reached.

**3.12.7** The lead glass of the fluorescent screen must have a lead equivalent of:

- i 1.5 mm for apparatus capable of operating up to 75 kV.
- ii 2.0 mm for apparatus capable of operating up to 100 kV.
- iii An additional 0.01 mm per kV above 100 kV.

**3.12.8** Foot switches must be so constructed that exposure does not take place if they are accidentally overturned.

### **3.13 Mass miniature radiographic equipment**

**3.13.1** The useful beam should be restricted to the fluorescent area of the screen and the beam should also be limited to the minimum consistent with the clinical requirements. A light-beam localizer should be used.

**3.13.2** The equipment must be so arranged and shielded that all staff associated with the procedure are afforded adequate protection during routine use without the necessity for protective clothing.

**3.13.3** High speed optical systems, which enable the dose to the patient to be reduced, should be used.

### **3.14 Dental radiographic equipment**

**3.14.1** Normally for dental radiography a field-defining spacer-cone (see Section 3.7.3) must be employed which provides a minimum focus skin distance of not less than 20 cm for equipment operating above 60 kV and not less than 10 cm for equipment operating at lower potentials. Open-ended cylindrical or divergent cones conforming with Section 3.10.4 should be used rather than the so-called 'pointer' cones. The field diameter at the cone end should not exceed 6 cm and must not exceed 7.5 cm.

**3.14.2** A timer must be provided (see Section 3.10.8).

**3.14.3** Installations operating up to 70 kV should be so arranged that the operator can remain at least one metre from the tube and patient; in the case of installations operating above 70 kV, the operator should be able to remain at least 1.5 metres away. Even under these conditions, protective panels having a lead-equivalent of not less than 0.5 mm should be used for work-loads exceeding 30 mA min per week.

### **3.15 Mobile and portable equipment**

**3.15.1** Those requirements in section 3.10 and 3.11 which are applicable must be observed in the case of mobile and portable equipment.

**3.15.2** The cable from the apparatus to the exposure switch must be at least 2 metres in length.

### **3.16 Protective clothing**

**3.16.1** Gloves and aprons are not designed to provide adequate protection from an unattenuated primary beam but only from primary radiation transmitted through the patient and from scatter.

**3.16.2** Gloves must have a protective equivalent throughout both front and back (including fingers and wrist) of not less than 0.25 mm lead for X-rays excited at voltages up to 150 kV.

**3.16.3** Body aprons must have a minimum lead-equivalent of 0.25 mm for X-rays excited at voltages up to 150 kV.

**3.16.4** Gloves and aprons should be examined visually at frequent intervals and must be examined radiographically at least annually to ensure that the protection afforded has not been impaired as a result of cracks in the material. A record of these examinations must be kept. (For gloves see British Standard 2606:1955<sup>37</sup> as amended, and for aprons see British Standard 3783:1964<sup>40</sup>). The protective material of the gloves should not have a permanent cover. The gloves should have a detachable cover of nylon or similar material so that any cracks which might develop may be revealed.

### **3.17 Small departments and other institutions without qualified radiographic staff**

**3.17.1** In some hospitals and other institutions, doctors or nurses who have no radiographic qualification are obliged occasionally to make an X-ray examination. No person should be allowed to do this until he has received appropriate instruction in the precautions necessary for safe operation. Responsibility for ensuring that this instruction has been given lies with the Controlling Authority. Controlling Authorities should appoint consultant radiologists to give further advice on suitable techniques to be used in these institutions.

# 4 THERAPEUTIC USES OF RADIATION BEAMS, REMOTELY OPERATED AFTER-LOADING EQUIPMENT, AND EXTRA-CORPOREAL BLOOD IRRADIATORS

## 4.1 General requirements

**4.1.1** This section emphasizes the recommendations for the protection of the staff from highly penetrating radiations and from high dose-rate beams from electron accelerators. It also includes recommendations about the measures necessary to minimize the radiation dose to those parts of the patient not included within the treatment beams and the risk of accidental gross over-exposure. The following requirements are intended to apply so far as is practicable to all equipment producing beams of ionizing radiation for therapeutic purposes (X-rays, gamma-rays, beta-rays, electrons, and neutrons). They also apply to remotely operated after-loading equipment using individual sources totalling 0.5 g radium-equivalent or more (see Section 4.5) and to extra-corporeal blood irradiators (see Section 4.6).

**4.1.2** The treatment room in which the radiation source is housed must be provided with structural shielding giving adequate protection. If the useful beam is always directed away from certain occupied areas then the barrier between the treatment room and these occupied areas may be designed to afford protection against leakage and scattered radiation only. Full protection commensurate with the use of the adjoining space must, however, be provided in all those occupied areas towards which the useful beam can be directed. (Details of the properties of shielding materials can be found in the Handbook of Radiological Protection, Part 1: Data<sup>45</sup>). Observation windows should be so located that they cannot be irradiated by the useful beam (see exception in Section 4.5.2). They must provide at least the same degree of protection as that required of the barriers in which they are located.

**4.1.3** Treatment rooms must be prominently marked with a symbol to indicate ionizing radiations (see Appendix F).

**4.1.4** Means must be provided for observing the patient and should be provided for communication with the patient from the control panel during treatment.

**4.1.5** A visible signal must be provided outside the treatment room to indicate that the radiation beam is in operation. Wherever possible, a similar visible signal should be provided inside the treatment room. A desirable additional safeguard is the provision of an independent radiation alarm system to guard against the consequences of failure of the visible indicators.

**4.1.6** Interlocks must be provided so that when any door or barrier (e.g. light beam or bar) to the treatment room is opened or interrupted the radiation beam is immediately switched off and cannot be re-energized until the interlock is reset. The reset switch should be provided near the exit from the room and it must be possible for the radiation beam to be re-energized only from the control panel. In cases where the Controlling Authority is satisfied that doors can be closed only by positive action, this action may be accepted as the reset mechanism.

**4.1.7** Except for radiation generated at not more than 50 kV, the operator should always be outside the room during any period whilst the beam is switched on. Only when it is unavoidable should a person, other than the patient, be in the treatment room during a treatment (e.g. when treating babies or mentally unstable persons and no alternative procedure is practicable). This person should not be the regular operator of the equipment, and must be provided with adequate protection (e.g. by shielding or distance).

**4.1.8** Any person who carries out any modification to or maintenance of any apparatus which might alter the output or quality of the radiation or the protection of the tube, must immediately attach to the apparatus an appropriate visible notification of such modification or maintenance and must on each occasion, inform (in writing) the Radiation Safety Officer and radiographer-in-charge; the latter must enter the details in a record book kept for the purpose. The equipment must not be used again until the physicist responsible for the equipment has been informed and until he has confirmed that it is safe and has completed such recalibration as he deems necessary.

**4.1.9** To avoid accidental over-exposure of patients, there must be a rigid procedure in operating apparatus and each member of the staff must be aware of this procedure and must clearly understand the extent of his own responsibility. The procedure must include the checking, by the person responsible for operating the machine, of the operating conditions of the apparatus on each occasion before a patient is treated.

## **4.2 X-ray beam installations**

**4.2.1** A therapeutic-type housing must be used (see Appendix G).

**4.2.2** Permanent cones or diaphragms used for collimating the useful beam must afford the same degree of protection as the therapeutic-type housing. Adjustable or removable beam-defining cones or diaphragms must be constructed so as to reduce the integral dose to the patient as much as practicable. The material of the cones or diaphragms must in no case transmit more than 2 per cent of the useful beam.

**4.2.3** Each accessible filter must be marked with its thickness and material, or in the case of a wedge filter with appropriate details (e.g. material and angle) which permit easy recognition of the filter in use. In the case of wedge filters, a system of coded interlocks should be provided. For low energy (50 kV or less) X-ray therapy machines, an interlocked system should be employed to control the maximum kilovoltage which may be used with a particular filter thickness.

**4.2.4** Unless it is possible rapidly to bring the X-ray output to the prescribed value, the housing must wherever practicable be fitted with a shutter, operated from the control panel, and of lead-equivalent not less than that of the tube housing. The position (open or closed) of the shutter must be indicated at the control panel. If a shutter is impracticable an integrating dosimeter must be provided.

**4.2.5** The equipment must be provided with an automatic timer or an integrating dosimeter to terminate the treatment after a pre-set time or dose. For equipment generating beams of energy greater than 2 MeV and dose rates of  $100 \text{ rad min}^{-1}$  or more in air at the treatment distance, there must be installed a dosimetry system which satisfies the conditions laid down in Appendix H.

**4.2.6** The use of low voltage equipment which requires to be held by the operator should be discouraged.

**4.2.7** For equipment not covered by Appendix H, the delivery of the required treatment dose should be controlled by either:

- i A calibrated beam-monitor dosimeter.
- ii A calibrated beam-monitor dose-rate meter together with a timer.
- iii Reference to calibration charts which give the dose rates at specified kilovoltages, tube currents, filters, sizes of applicators and focus skin distances. The dose rates given on the charts must be frequently checked against an independent dosimeter. These charts must be displayed as near to the control panel of each generator as practicable and must show the calibration dates which should be signed or initialled by the physicist responsible.

A transmission monitoring chamber in the useful beam should be used for observing the constancy of the dose rate (see Section 4.2.10).

**4.2.8** All equipment should be provided with a system which automatically and permanently records the time or magnitude of each exposure.

**4.2.9** A physicist must be responsible for ensuring that all X-ray apparatus used for therapeutic purposes is calibrated at intervals of not more than four weeks. The measurements made at each calibration must be sufficient to ensure that the output dose rate for all operational conditions can be estimated. Where output dose rates vary by more than 5 per cent between successive calibrations more frequent calibrations should be carried out, possible causes of variation investigated, and appropriate action taken.

**4.2.10**

- i Wherever practicable an ionization monitor should be fitted into the tube housing to indicate the constancy of the X-ray output. The monitor should be on the patient's side of any removable filters. If, at any time, this monitor shows a variation of output of 5 per cent or more from normal, it should be reported immediately to the physicist responsible as it may indicate a fault. The causes of any gross changes in the output must be investigated. Where these appear to concern protection the Radiological Safety Officer must be informed. For high energy equipment producing X-rays above 2 MeV with output of more than  $100 \text{ rad min}^{-1}$  in air at the treatment distance, the conditions laid down in Appendix H must be satisfied.
- ii Where a monitor is not fitted, the output under standard conditions should be checked frequently, preferably at least once each working day, and any variations from normal of 5 per cent or more reported to the physicist responsible for the calibration.
- iii Whenever adjustments, other than normal operation of the controls, have been made to the equipment, following breakdown or for any other reason, the physicist must be responsible for ensuring that the apparatus is recalibrated before it is again used for the treatment of patients.

**4.2.11** Dosemeters used for calibrations and check of output must be maintained in good condition and appropriate tests made to ensure that their sensitivity remains constant. They should be checked at intervals of not more than one year against a recognized secondary standard meter over the range of radiation qualities normally used.

**4.2.12** It is not the function of this Code to give details of the procedures to be adopted for ensuring that the equipment is properly calibrated. This is the responsibility of a suitably experienced physicist. Recommendations for the procedures to be adopted are given in the Codes published by the Hospital Physicists' Association<sup>65,66,67</sup> and in other standard texts.

**4.2.13** Neutrons may be produced by X-rays of energy exceeding about 10 MeV and consequently may form a significant fraction of the stray radiation from very high energy equipment. In addition, radioactivity may be induced in surrounding materials, including air and dust. The extent of these hazards should be assessed in the planning stage and any necessary safety measures, e.g. choice of appropriate wall material and forced ventilation, incorporated into the design of the treatment room. Following installation of the generator, a detailed survey should be carried out to determine the activity levels within the room and any further appropriate safety precautions, e.g. delay in entering the room, should be specified. The possibility of induced activity must govern the choice of materials used for collimating the beam and for the local shielding of the patient. When maintenance work has to be done in the vicinity of the X-ray target, the filter, or the magnet system of any high energy machine, monitoring should first be carried out. Expert advice on these problems should always be obtained at the planning stage from either the Department of Health and Social Security, the Scottish Home and Health Department, the Ministry of Health and Social Services, Northern Ireland, the Welsh Office, or the National Radiological Protection Board.

### **4.3 Electron beam units**

**4.3.1** Normally an installation designed for the production of X-rays and satisfying the requirements of Sections 4.1 and 4.2, will provide adequate protection when used for the production of an electron beam. The shielding of the treatment room in those directions in which the useful electron beam can be directed should, however, take into account the production of bremsstrahlung in the shield itself. Consideration should also be given to the need for a solid barrier such as a wooden door at the maze entrance.

**4.3.2** In an installation for the production of electron beams only, the housing should be designed to minimize the emission of bremsstrahlung. Exposure rates in the neighbourhood of the housing should conform to the requirements of a therapeutic-type housing (see Appendix G).

**4.3.3** Unless it is possible rapidly to bring the electron output to the prescribed value, the housing must wherever practicable be fitted with a

shutter, operated from the control panel, and of lead equivalent not less than that of the tube housing. The position (open or closed) of the shutter must be indicated at the control panel.

**4.3.4** The equipment must be provided with an automatic timer and an integrating dosimeter, to terminate the treatment after a pre-set time or dose. For equipment producing electrons of energies above 2 MeV and dose rates of  $100 \text{ rad min}^{-1}$  or more in air at the treatment distance, there must be installed a dosimetry system which satisfies the conditions laid down in Appendix H.

**4.3.5** For equipment not covered by Appendix H, the delivery of the required treatment dose should be controlled by either:

- i A calibrated beam-monitor dosimeter.
- ii A calibrated beam-monitor dose-rate meter together with a timer.
- iii Reference to calibration charts which give the dose-rates under specified operating conditions; the dose-rates given on the charts must be frequently checked against an independent dosimeter. These charts should be displayed as near to the control panel of each generator as practicable and must show the calibration dates which should be signed or initialled by the physicist responsible.

**4.3.6** All equipment should be provided with a system which automatically and permanently records the time or magnitude of each exposure.

**4.3.7** A physicist must be responsible for ensuring that all electron beam apparatus used for therapeutic purposes is calibrated daily. The measurements made at each calibration must be sufficient to ensure that the output dose-rate for all operational conditions can be estimated.

**4.3.8**

- i An ionization monitor must be fitted into the tube housing to indicate the constancy of the electron output. If, at any time, this monitor shows a variation of output of 5 per cent or more from normal, it should be reported immediately to the physicist responsible as it may indicate a fault. The causes of any gross changes in the output must be investigated. Where these appear to concern protection the Radiological Safety Officer must be informed.
- ii Whenever adjustments, other than normal operation of the controls, have been made to the equipment, following breakdown or for any other reason, the physicist must be

responsible for ensuring that the apparatus is recalibrated before it is again used for the treatment of patients.

**4.3.9** Dosemeters used for calibrations and check of output must be maintained in good condition and appropriate tests made to ensure that their sensitivity remains constant. They should be checked at intervals of not more than one year against a recognized secondary standard meter over the range of radiation qualities normally used. It is not the function of this Code to give details of the procedures to be adopted for ensuring that the equipment is properly calibrated. This is the responsibility of a suitably experienced physicist. Recommendations for the procedures to be adopted have been produced by the Hospital Physicists' Association<sup>64</sup> and by the American Association of Physicists in Medicine<sup>68</sup>.

**4.3.10** Neutrons may be produced by bremsstrahlung generated by electrons of energy exceeding about 10 MeV and consequently may form a significant fraction of the stray radiation from very high energy equipment. In addition radioactivity may be induced in surrounding materials, including air and dust. The extent of these hazards should be assessed in the planning stage and any necessary safety measures, e.g. choice of appropriate wall material and forced ventilation, incorporated into the design of the treatment room. Following installation of the generator, a detailed survey should be carried out to determine the activity levels within the room and any further appropriate safety precautions, e.g. delay in entering the room, should be specified. The possibility of induced activity must govern the choice of materials used for collimating the electron beam and for the local shielding of the patient. When maintenance work has to be done on any part of the equipment in the vicinity of the path of the electron beam, monitoring should first be carried out. Expert advice should always be obtained at the planning stage from either the Department of Health and Social Security, the Scottish Home and Health Department, the Ministry of Health, Northern Ireland, the Welsh Office, or the National Radiological Protection Board.

#### **4.4 Gamma-ray and beta-ray beam units**

**4.4.1** A teletherapy-type source housing must be used (see Appendix G).

**4.4.2** Standard source capsules should be used whenever practicable.

**4.4.3** Permanent cones or diaphragms used for collimating the useful beam must afford the same degree of protection as the source

housing. Adjustable or removable beam-defining cones or diaphragms must be constructed so as to reduce the integral dose to the patient as much as practicable. The material of the cone or diaphragm must in no case transmit more than 2 per cent of the useful beam.

**4.4.4** A remotely operated beam control mechanism must be used which is capable of functioning in any orientation of the housing. The mechanism must be so constructed as to return the source automatically to the 'OFF' position both at the predetermined end of an exposure and in the case of any breakdown or interruption of the activating force. The source must stay in the 'OFF' position when the force is restored, until the mechanism is operated from the control panel.

**4.4.5** In addition to the normal beam control mechanism, the apparatus should be so constructed that, in an emergency, the source can be manually returned to the safe position with the least possible exposure to the staff concerned.

**4.4.6** The equipment must be provided with an automatic timer or an integrating dosimeter, to terminate the treatment after a pre-set time or dose.

**4.4.7** The surface of the equipment housing the source capsule, particularly the beam aperture, must be tested for leakage of radioactive substances from the capsule at the time of installation of the source and at least once a year thereafter and whenever any damage to the source is suspected. A record must be kept of the results of all such tests (see Sections 9.2.15 and 9.2.20). If the test indicates the presence of free activity greater than 0.05 microcurie the source capsule must be considered to be leaking and arrangements must be made immediately for its repair. In carrying out leakage tests of beta-ray sources care must be taken to avoid damaging the window through which the beta-rays are emitted. Guidance on carrying out leakage tests is given in H.P.A. Report Series No. 1<sup>62</sup>.

**4.4.8** As a teletherapy source is still emitting radiations even when in the 'OFF' position, the room should at all other times be occupied only for necessary purposes associated with the operation and maintenance of the apparatus and other essential activities. This does not preclude the siting in the treatment room of other therapy apparatus so long as the radiation field does not exceed that recommended for a single unit (see Appendix G).

**4.4.9** A physicist must be responsible for ensuring that all gamma and beta-ray apparatus is checked for correct operation and applicability of the output data in use, at least once every four weeks.

#### **4.5 Remotely operated after-loading equipment using individual sources totalling 0.5 g radium equivalent or more**

**4.5.1** This section applies to remotely controlled after-loading equipment for the insertion of sources into patients where the sources are of sufficient activity to necessitate the provision of substantial shielding. The provisions for the shielding of this equipment differ from those for gamma-ray beam units because the beam is not collimated and the observation window will be directly irradiated. The section is not intended to cover those remotely controlled units which may be used in wards (i.e. using sources totalling less than 0.5 g radium equivalent). These latter units come within the provisions of Section 5 of the Code dealing with protection from small sealed radioactive sources.

**4.5.2** The treatment room in which the storage container is housed must be provided with structural shielding giving adequate protection to the adjoining space. If a baffle wall is used to prevent direct radiation striking the door, the protection provided by the latter may be reduced. In calculating the thickness of such a secondary barrier, allowance should be made for the fact that the area of wall, floor, and ceiling which is a source of once scattered radiation is much greater than that associated with a collimated beam unit. The observation window will receive direct radiation and must provide at least the same degree of protection as that required of the barrier in which it is located.

**4.5.3** Interlocks must be provided so that when any door or barrier (e.g. light beam or bar) to the treatment room is opened or interrupted the radioactive sources are immediately returned from the patient to the shielded store and cannot be returned to the patient until the interlock is reset. The reset switch should be provided near the exit from the room, and it must be possible to re-energize the source drive mechanism only from the control panel. In cases where the Controlling Authority is satisfied that doors can be closed only by positive action, this action may be accepted as the reset mechanism.

**4.5.4** Since personnel may spend considerable time in the vicinity of the storage container during the preparation of the patient for treatment, the storage container must be shielded for these working conditions (see Appendix G).

**4.5.5** The remotely controlled source drive mechanism must be constructed to return the sources automatically to the storage container at the predetermined end of an exposure, in the case of the operation of the interlock circuits, or in any breakdown. The sources must remain in the storage container when the power is restored and until the drive mechanism is operated from the control panel.

**4.5.6** In addition to the normal source control mechanism, the equipment should be constructed so that in an emergency the sources can be returned quickly to the storage container by manual operation preferably from the control panel with the least possible exposure to the staff concerned.

**4.5.7** The equipment must be provided with an automatic timer to terminate the treatment after a preset time.

**4.5.8** The internal surfaces of the source supply tubes must be tested for leakage of radioactive substance from the source capsules at the time of installation of the sources, at least once a year thereafter, and whenever damage to the sources is suspected. A record must be kept of the results of all such tests (see Sections 9.2.15 and 9.2.20). If the test indicates the presence of free activity greater than 0.05 microcurie, one or more of the source capsules must be considered to be leaking. The source capsules must then be tested individually and arrangements must be made immediately for any repairs. Guidance on carrying out leakage tests is given in H.P.A. Report Series No. 1<sup>62</sup>.

**4.5.9** As the sources are still emitting radiations even when in the storage container, the room should be occupied only for necessary purposes associated with the operation and maintenance of the apparatus and other essential activities. This does not preclude siting in the treatment room of other therapy apparatus so long as the radiation field does not exceed that recommended for a single unit (see Appendix G).

## **4.6 Extra-corporeal blood irradiators**

**4.6.1** This section refers to sealed radioactive sources of 0.5 curie or more, emitting beta-rays and gamma-rays used for extra-corporeal irradiation of blood.

**4.6.2** The housing of the source must be so designed that in no circumstances can the radioactive source be viewed directly.

**4.6.3** Manipulation of the source between the 'ON' and 'OFF' positions must be by remote control and there should be a visual indication when the source is in the 'ON' position.

**4.6.4** The source housing should be tested for radioactive contamination initially, at least once a year thereafter, and whenever damage to the source is suspected. If the test indicates the presence of free activity greater than 0.05 microcurie the source capsule must be considered to be leaking and arrangements made for its inspection and repair. In carrying out leakage tests of beta-ray sources care must be taken to avoid damaging the window through which the beta-rays

are emitted. A record must be kept of all such tests (see Sections 9.2.15 and 9.2.20). Guidance on carrying out leakage tests is given in H.P.A. Report Series No. 1<sup>62</sup>.

**4.6.5** When not in use the equipment must be so stored that it will not give rise to the excessive exposure of any person.

**4.6.6** When the equipment is in use the exposure rate of the leakage radiation must not exceed  $2 \text{ mR h}^{-1}$  at a source distance of 1 metre (see paragraph 1 of Appendix G for assessing compliance with this requirement).

**4.6.7** When the equipment is in operation a symbol indicating ionizing radiations (see Appendix F) must be prominently displayed on or near it.

**4.6.8** Where possible, treatment should be carried out in wards having only 1 or 2 beds. Where a general ward is used, the equipment should not be less than 2.5 metres from the centre of any bed occupied by another patient.

**4.6.9** Charge nurses, sisters, nurses and other persons must not remain unnecessarily in the vicinity of the equipment.

**4.6.10** Visitors should not be allowed during treatment periods, except at the discretion of the Radiological Safety Officer.

#### **4.7 Neutron beam units and other future developments**

**4.7.1** There are at present insufficient data on which to lay down Code requirements for neutron beam units which might be used for therapeutic purposes, though the problems are being actively studied. In the interim, when any project involving neutrons for therapy reaches the planning stage, reference should be made to either the Department of Health and Social Security, the Scottish Home and Health Department, the Ministry of Health and Social Services, Northern Ireland, or the Welsh Office for advice. Similar action should be taken in regard to any other future developments in usage of ionizing radiations that are not covered by this Code.

## 5 THERAPEUTIC USES OF SMALL SEALED RADIOACTIVE SOURCES

### 5.1. General requirements

**5.1.1** This section sets out the necessary precautions to be taken in the use of small sealed sources for radiotherapy. This includes the preparation, sterilization, and documentation of these sources, but section 9 should be consulted for details of correct storage arrangements and the action to be followed in the event of a reported loss of or damage to a source. The sources considered include for example radium, caesium-137 and cobalt-60 needles and tubes, gold-198 grains, tantalum-182 and iridium-192 grains and wires, and strontium-90 and other beta-ray plaques.

**5.1.2** A separate room must be provided for the 'make-up' and cleaning of sources and applicators and this room should only be occupied during such work. The door of the room must be marked with a symbol indicating ionizing radiation (see Appendix F). The room must be adequately ventilated. The placing of objects in the mouth, eating, smoking, drinking, or the application of cosmetics whilst within the room must be prohibited. Since the use of personal handkerchiefs must be avoided there must be an adequate supply of paper handkerchiefs. A drinking fountain, however, is admissible.

**5.1.3** A permanent record must be kept of the issue, distribution and return of all sources (see also Section 9.2.16). Adequate records must also be kept of the administration of permanent implants.

**5.1.4** In order to ensure the minimum irradiation of personnel engaged in the preparation or application of sources, appropriate handling tools or implant instruments must be used at all times. These tools should be constructed so as to provide the maximum handling distance compatible with effective manipulation. All operators must have adequate training in these manipulative procedures. Sources or loaded source containers must not, under any circumstances, be picked up directly by hand. In order to ensure that doses in excess of the quarterly maximum permissible levels (see Appendix B) are not received by members of the staff a rota system of duties must, where necessary, be instituted.

**5.1.5** All appliances should be carefully designed for ease of handling. For example, needle eyes should be designed for easy threading and thread ends subject to fraying should be prepared with wax; screw threads should be of the optimum size and pitch to allow fast 'jam proof' operation. All steps possible in the preparation and

assembly of appliances must be carried out before the insertion of the source.

**5.1.6** When multiple needles or capsules of the same appearance but of different strengths are used, they must be identified with different coloured threads, beads, or other means when in clinical use.

**5.1.7** The number and position of removable sealed sources in or on the patient must be regularly checked. Dressings and excreta from patients receiving treatment with sealed sources of radioactive substances must not be disposed of unless monitoring has shown that they are not radioactive, or until all the radioactive sources have been accounted for.

**5.1.8** All sealed radioactive sources in which the radioactive substance is encapsulated or bonded in inactive material must be tested for leakage and surface contamination initially, at least once a year thereafter, and whenever damage to the source is suspected. If the test indicates the presence of free activity greater than 0.05 microcurie the source must be considered to be leaking unless the activity can be identified as surface contamination which can be removed or will decay to such an extent that the result of a subsequent test is found to be satisfactory. In carrying out leakage tests of beta-ray sources care must be taken to avoid damaging the window through which the beta-rays are emitted. Records of all leakage tests must be entered in the sealed sources register (see Sections 9.2.15 and 9.2.20). Guidance on carrying out leakage tests is given in H.P.A. Report Series No. 1<sup>62</sup>.

**5.1.9** Whenever there are reasonable grounds for believing that radioactive substances are leaking, or are liable to leak, from a sealed source, that source must at once be placed in an airtight container pending repair by a competent person. Leaking radium sources must only be repaired by the Radiochemical Centre, Amersham, whose advice regarding the return of such sources should be sought.

## **5.2 Sterilization and disinfection of small sealed sources**

**5.2.1** It is most important that in sterilizing or disinfecting small sealed sources (e.g. radium needles, gold grains, etc.) adequate precautions should be taken to avoid the following:

- i Radiation exposure of nursing and other staff.
- ii Damage to the sources.
- iii Loss of sources.

There are several possible methods of dealing with sources, each having particular merit for certain types of work. Not all these methods produce complete sterilization and the radiotherapist or

other clinician concerned should decide in each case whether such is required or whether disinfection will suffice. Advice on the most effective method of achieving the desired degree of sterilization or disinfection should be sought from the consultant pathologist. Before sources are sterilized or disinfected they should be thoroughly cleaned (see Section 5.2.4).

**5.2.2** So far as is practicable autoclaves, hot air ovens, and other equipment used for sterilizing or disinfecting sources should be screened with lead or other heavy protective material. Provision must be made to prevent the loss of the source from the equipment.

**5.2.3** The following special precautions need to be taken when sterilizing or disinfecting sealed sources:

- i Sterilizers must be fitted with a cut-out that will prevent the temperature of the source rising above 180°C.
- ii Single loaded radium sources (usually of pre-1937 manufacture) must not be steam sterilized.
- iii All sources must be visually examined before they are sterilized or disinfected and any found to be damaged must be reported at once to the custodian and not sterilized or disinfected. (See also Section 5.1.9).
- iv When ethylene oxide is used to sterilize sources mounted in plastic or rubber sufficient time must elapse after sterilization for it to diffuse out.
- v Some disinfecting solutions may attack the enamel identification marks on some radium appliances; any such damage must be reported at once to the Custodian.

**5.2.4** Sealed sources should be cleaned before being returned to the store, particular care being taken with thin-walled sources. Methods similar to the following are suitable:

- i Soaking for about an hour, if necessary, in a suitable disinfectant or (if dried blood is present) in a solution of hydrogen peroxide or (if mould material is adherent) in xylene.
- ii Thoroughly rinsing in warm or boiling water.
- iii Ultrasonic generators of low power in cleansing fluids may be used.

If the containers are of steel, which might rust, they should be rinsed in surgical spirit or alcohol prior to drying. Abrasive substances (e.g. metal cleaners and polishes) must not be used, and sources must not be allowed to come into contact with mercury or mercury salts, iodine and solutions of hypochlorites, or corrosive substances. Difficulties in cleaning can be avoided if blood and tissue are not

allowed to dry on appliances, this can be effected by transferring the container, immediately after removal from the patient, to a solution such as normal saline.

### **5.3 Loss or breakage of a small sealed source**

**5.3.1** An emergency procedure to be adopted in the case of loss or breakage of a radioactive source must be specified and notices indicating the action to be taken must be displayed in each room where such sources are handled or employed. All staff should be fully aware of their duties in such an event (see Sections 9.2.21, 9.2.22, and 9.2.23).

**5.3.2** On account of the high radiotoxicity and long half-life of radium-226, special care is necessary in the event of the fracture of a radium container which might lead to the dispersal of radium compound and any intake of radium into the body; this must be considered as a possibility, particularly during some sterilizing procedures. Apart from regular inspection of sealed sources, monitoring for contamination should include areas where radium needles are manipulated so that the presence of radium contamination will be detected as soon as possible and before the contamination has spread widely. Precautions to prevent the spread of contamination should be rigorously applied. The clean-up of any substantial radium contamination will call for special care and, possibly, outside expert assistance. In any case protective clothing and respirators should be used. Similar stringent precautions are necessary in the event of contamination arising with other long-lived nuclides of high or medium toxicity.

### **5.4 Beta-ray sources**

**5.4.1** Suitable shields or baffles must be provided, where required, to ensure adequate protection when manipulating beta-ray sources. In order to prevent the head from being placed too near the source, and to protect the eyes and face from beta-rays, a transparent plate of adequate thickness should be mounted or worn between the source and the face of the operator.

**5.4.2** It should be recognized that pure beta-ray sources will emit bremsstrahlung and may emit characteristic X-rays and annihilation radiation or both. In the case of large sources these radiations may present a hazard which should be evaluated and the necessary precautions taken. Some beta-ray sources are also gamma-ray emitters and appropriate protection should be provided (see Section 5.5).

**5.4.3** Sources intended for the utilization of beta-rays outside the container require a thin window. When not in use this window must be covered by a shield of sufficient thickness to stop all beta-radia-

tions. When cleaning the sources the precautions referred to in Section 5.4.1 should be observed and care should be taken to avoid damaging the window.

## 5.5 Gamma-ray sources

**5.5.1** Benches used for the preparation, assembly and cleaning of gamma-ray source capsules and appliances must be provided with adequate protection for the operator and for other persons either associated with the work or in adjacent areas. (For data on the properties of protective materials see the Handbook of Radiological Protection, Part 1: Data<sup>45</sup>).

**5.5.2** In operating theatres and other treatment rooms where gamma-ray sources are applied to patients all practicable radiation shielding must be provided. Protective barriers may be mounted on wheels and provided, where necessary, with sterile drapes. The barriers should be so designed as to give protection in all directions where persons are usually stationed during radiotherapeutic procedures. Gamma-ray sources must remain behind protective barriers as long as possible and be removed individually as required for application to the patient. In all cases expeditious handling and the use of suitable instruments (see Section 5.1.4) will reduce the hazard. The development and use of after-loading techniques should be encouraged to reduce the dose received by staff.

## 5.6 Protection of persons in proximity to patients undergoing treatment with small sealed sources

**5.6.1** The local rules for the protection of persons in proximity to patients undergoing treatment with sealed radioactive sources should be based on the following requirements:

- i Beds in which there are patients undergoing treatment with radioactive sources must carry a notice using the standard symbol (see Appendix F) indicating the fact. The notice should give details of the number and nature of sources, total activity of the radioactive substances, the time and date of application and removal, and relevant nursing instructions.
- ii The Radiological Safety Officer of the relevant department must measure or otherwise estimate the maximum gamma-ray exposure rate at a distance of 1 metre from each patient undergoing treatment. If this exposure rate exceeds  $5 \text{ mR h}^{-1}$  the notice must in addition indicate that an external radiation hazard exists, and the Radiological Safety Officer must give instructions regarding the daily time allowable for nursing procedures and visitors.
- iii Patients with sources in or upon their bodies must not be permitted to leave the ward or treatment room without the

approval of the appropriate medical officer. (Rules for patients leaving a hospital after administration of radioactive substances are given in Section 8).

- iv Nursing staff and other persons must not remain unnecessarily in the vicinity of patients undergoing treatment with gamma-ray sources. Where possible, nursing procedures should be postponed until after the sources have been removed.
- v It may be necessary to reallocate duties for staff who are confirmed to be pregnant and also to exclude visitors who may be pregnant.
- vi Where possible such treatment should be carried out in wards having only 1 or 2 beds, care being taken to ensure that adjoining rooms are adequately protected. Where a general ward is used, the beds of the patients under treatment must be distributed as widely as possible throughout the ward and there should be not less than 2·5 metres between bed centres.

# 6 THERAPEUTIC AND DIAGNOSTIC USES OF UNSEALED RADIOACTIVE SUBSTANCES

## 6.1 Control of hazards from unsealed radioactive substances

**6.1.1** A radiation hazard may arise from unsealed radioactive substances either through external irradiation of the body, or through the entry of radioactive substances into the body. The main precautions required in dealing with external irradiation are similar for both sealed sources and unsealed substances and depend essentially on the physical characteristics of the radiation emitted and on the physical half-life of the radionuclide. In addition unsealed radioactive substances may produce a further external radiation hazard as a result of contamination.

**6.1.2** When unsealed radioactive substances enter the body, the radiation dose to the body or to particular organs will depend both on the physical properties of the radionuclide concerned and on the manner in which the substance is metabolized. The International Commission on Radiological Protection has recommended maximum permissible values for the doses to the whole body and to particular organs. From metabolic data, the Commission has also evaluated maximum permissible body burdens and maximum permissible concentrations in air and water of radionuclides for continuous exposure and maximum permissible intakes of radionuclides for short-term exposure, as shown in Appendix C. Using the calculated values of maximum permissible body burden and maximum permissible concentration in air, the International Atomic Energy Agency has derived a classification of radionuclides according to relative radiotoxicity. The classification of those radionuclides which are used in the hospitals in the United Kingdom is given in Table 1 of this Section (page 47). This classification indicates the comparative hazard involved in work with various radionuclides; however, it should be noted that the classification may require modification for radionuclides incorporated in complex chemical compounds.

**6.1.3** It is important that unsealed radioactive substances, even in very small amounts, should be manipulated only in working areas recognized and equipped for this work.

**6.1.4** The design of all rooms in which unsealed radioactive substances are used, the design of all equipment required in their use, and the procedures involved in work with such substances must be aimed at:

- i Minimizing the radiation exposure of persons referred to in Section 1.2.1.i.
- ii Limiting the radiation exposure of patients to that consistent with medical requirements.
- iii Minimizing the radiation exposure of persons referred to in Section 1.2.1.iii which arises from patients undergoing treatment with radioactive substances.
- iv Controlling the spread of radioactive substances into the working environment.

**6.1.5** Work with unsealed radioactive substances in hospitals should be governed by clearly understood rules of procedure, so that efficient practices can be organized and the control of hazards becomes an established routine. Adequate records must be kept including a record of all administrations of radioactive substances (see Section 9.2.27).

**6.1.6** In the following sections, the basic principles for general work with unsealed radioactive substances in hospital laboratories are developed and subsequently related to the wards and other working areas.

## **6.2 Design of laboratories and radioisotope departments**

**6.2.1** The requirements for hospitals using unsealed radioactive substances vary with the types of clinical tests being undertaken and the extent to which therapy is carried out. The Radiological Protection Adviser should make detailed recommendations affecting the design of new laboratories and other working areas, and also should consider changes that may become necessary from time to time.

**6.2.2** Where unsealed radioactive substances are used either in therapy or diagnosis, laboratories and areas should be provided for the following types of work:

- i Radionuclide dispensing and storage, incorporating a washup area.
- ii Excreta and specimen storage, and radioactive waste disposal, with measuring equipment and sluice.
- iii Radionuclide administration to patients.
- iv Clinical measurements.
- v Sample measurements.
- vi Decontamination.

**6.2.3** In the following sections, outline descriptions are given of the requirements for such working areas. The space allocated and the extent to which the areas are separated will depend upon the scope of the service provided.

#### 6.2.4 In laboratories and working areas:

- i The floor, walls, and benches should be finished with smooth, continuous, and non-absorbent surfaces which can be cleaned easily.
- ii The floor and benches must be strong enough to support the weight of any necessary shielding materials.
- iii A wash-hand-basin, fitted with foot, knee or elbow operated taps, should be provided.

#### 6.2.5 The radioisotope dispensary will be the principal area in which radiochemicals will be handled in the hospital, and should have the following additional special features:

- i Adequate storage space, so that essential equipment used in the dispensary is kept there, thus minimizing the risk of spreading contamination to other areas.
- ii One or more fume cupboards, or glove boxes, designed for ease of decontamination (see Sections 6.2.10 and 6.2.11). These can be used to advantage in confining and preventing the spread of radioactive substances (see Section 6.4.3).
- iii An entry lobby where protective clothing can be kept ready for use on entering the dispensary.
- iv An adequately protected store for radioactive substances.
- v Temporary adequately protected storage for solid radioactive waste arising from dispensing procedures. Disposable paper sacks of distinctive colours are convenient for this purpose.
- vi A limited number of places, designated and clearly marked for the disposal of radioactive liquid waste.
- vii Shielding in order to protect the worker from unnecessary exposure to external radiation. (When this is effected by a vertical lead screen mounted between the worker and the source on top of a bench then adequate protection in all directions must be ensured. For instance, the worker must be adequately protected from gamma-radiation which may penetrate the bench top; also persons in rooms or corridors adjacent to the dispensing area must be protected from gamma-radiation which may penetrate the floor, walls, or ceiling of the radioisotope dispensary).
- viii A washup area.
- ix Adequate ventilation in general by the continuous movement of air into the fume cupboard (see Section 6.2.10).

#### 6.2.6 Although collection of excreta in hospitals is not required for disposing of radioactive waste, such collection is sometimes needed for clinical reasons and a store should be provided for the temporary

retention of specimens. If therapeutic administrations are being carried out, the store should be shielded. The store should have or be situated close to a sluice and a washup unit. If measurements of radioactivity in excreta are required, the measuring equipment should be provided in or adjacent to this store in order to minimize the risk of spreading contamination.

**6.2.7** In addition to the general requirements outlined in Section 6.2.4, the area for radionuclide administration should be large enough to provide ample space not only for the patient and staff, but also for any trolleys of equipment used in the administration of radioactive substances. This also applies in circumstances where radioactive substances may be administered to patients in areas used for clinical measurements (e.g. in dynamic investigations).

**6.2.8** Since no dispensing or preparation of samples will normally be carried out in areas set aside for sample measurements, the structural requirements of such areas are governed chiefly by the equipment to be used. However, since a high standard of radioactive cleanliness is required and there is some risk of spills, the floor, walls and benches should be finished with smooth surfaces which can be easily cleaned.

**6.2.9** In order to deal with decontamination of persons, an area should be designated for this purpose equipped to carry out procedures as described in Section 6.8. (As part of National Arrangements for dealing with Incidents involving Radioactivity [NAIR] a number of hospitals are prepared to accept radiation casualties and, therefore, will already have made adequate provision for the decontamination of persons).

**6.2.10** Any fume cupboards must have an efficient mechanical exhaust draught system to prevent the spread of contamination into the working area. Fume cupboards which are designed to draw air only from the working area must have an air flow through an opening, when the window is closed to the working position of at least  $0.5$  linear msec $^{-1}$ . Fume cupboards which are designed to draw part of the air only from the working area should have an air flow across the opening which is sufficient to provide at least the same degree of containment. Details of the design of fume cupboards are given in British Standard 3202<sup>39</sup>. The exhaust should be discharged through ducting to the outside of the building at a carefully selected point or points not in close proximity to windows and air intakes. Provided each outlet point is well selected, filters will not be necessary for the amounts of radioactivity normally handled in hospitals. Smoke tests are a useful aid in investigating an installation to verify that the exhaust system will be adequate in adverse circumstances.

(e.g. when windows and doors are open and the wind conditions are unfavourable) and will prevent radioactive dust and vapours escaping from the fume cupboard directly into the working area or into the air of neighbouring rooms through the external vent. Consideration should be given to the possibility of having to decontaminate the exhaust ducting if long-lived radioactive substances (e.g. with radioactive half-life greater than 100 days) are used in the fume cupboard.

**6.2.11** A glove box fitted with an exhaust fan and ducting to the outside of the building, and operated under slightly reduced pressure, can afford a useful alternative to a fume cupboard. It has the advantage of requiring a very small air flow and thus does not disturb significantly the existing provision for heating the department. Moreover, it is often possible to convey the exhaust air more conveniently to the outside without disturbing the building structure.

**6.2.12** Laboratories and other working areas used for manipulation of unsealed radioactive substances will need equipment kept specifically for this purpose. This equipment should include:

- i Tongs, forceps, trays and appropriate apparatus for remote handling.
- ii a Containers for radioactive substances incorporating the necessary shielding as close to the source as possible.  
b Double-walled containers (the outer wall being unbreakable) in which to keep liquid samples.
- iii A drip tray over which all manipulations should be carried out, with a view to minimizing the spread of contamination due to breakages or spills.
- iv Compression bulbs to operate pipettes or wash-bottles; alternatively, hypodermic syringes to replace pipettes.
- v Radiation-monitoring equipment.
- vi Equipment for the assay of stock solutions and the radioactive substances prepared for administration to patients (see Section 6.4.2).

**6.2.13** Experience with radioactive substances has shown that standards of laboratory design and equipment may be classified conveniently into three grades (A, B, and C) each grade being appropriate for particular ranges of activity for different toxicities of radionuclides:

- i Grade C laboratory: for the manipulation of such activities as present a small degree of hazard (see Table 2 of this Section [page 48]) few modifications are needed in any modern conventional chemical laboratory having floors covered with sheet linoleum or similar material. Work-

benches should be provided with non-absorbent tops or with disposable covers. There should be at least one good fume cupboard with induced draught. The exhaust air should be carried outside the building but need not be filtered.

- ii Grade B laboratory: for work with activities of radioactive substances of the order shown in Table 2 of this Section (page 48), greater care in design is needed to facilitate the control of contamination. Design recommendations have been given by the International Atomic Energy Agency in Safety Series No. 1<sup>31</sup>, and the International Commission on Radiological Protection in ICRP Publication No. 5<sup>19</sup>.
- iii Grade A laboratory: for higher levels of toxicity and for complex procedures likely to incur high risks of contamination, a specially designed laboratory is necessary. It is unlikely that there will be need for a Grade A laboratory for clinical work in hospitals. However, if there is any doubt about this in a particular instance, reference should be made to the National Radiological Protection Board.

From the descriptions given above, it will be seen that in general the radioisotope dispensary should be of grade B standard whilst other areas should be of Grade C.

### **6.3 Toxicity of radionuclides and nature of procedures appropriate to the various grades of laboratory**

**6.3.1** The radionuclides commonly used in hospitals are classified in Table 1 of this Section (page 47) according to their relative radio-toxicity per unit activity, † and, in each of the four classes, are listed in order of increasing atomic number. The classification is based on the recommendations of the International Commission on Radiological Protection.

**6.3.2** Table 2 of this Section (page 48) gives the activities of unsealed radionuclides of different toxicities which can be used at any one time in the three grades of laboratory. Below the table are given the values of the modifying factors for various procedures. It must not be assumed that the ranges are fixed so precisely that no latitude is allowed in any circumstances. The Radiological Protection Adviser should be consulted in particular cases where it is desired to use larger activities than those specified in the table for a certain grade of laboratory. However, it should also be remembered that since the hazard may depend on the chemical forms of the radioactive substances, it may be necessary to restrict the activities to less than those shown in Table 2 in some cases.

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† A complete classification of radionuclides is given in Appendix L.

Table 1

## CLASSIFICATION OF RADIONUCLIDES USED IN HOSPITALS IN THE UNITED KINGDOM

High Toxicity	Medium Toxicity		Low Toxicity
(class 1)	Upper Sub-Group A (class 2)	Lower Sub-Group B (class 3)	(class 4)
Lead-210	S	Sodium-22	Carbon-14
Radium-226	S	Chlorine-36	Fluorine-18
Californium-252	S	Calcium-45	Sodium-24
		Cobalt-56 +	Phosphorus-32
		Cobalt-60	Sulphur-35
		Germanium-68 + P	Chlorine-38
	S	Strontium-90	Potassium-42
		Iodine-125 +	Potassium-43 +
		Iodine-131	Calcium-47
	S	Caesium-137	Scandium-47
	S	Thulium-170	Chromium-51
	S	Tantalum-182	Iron-52 +
	S	Iridium-192	Iron-55
	S	Thallium-204	Iron-59
		Radium-224	Cobalt-57
			Cobalt-58
			Copper-64
			Zinc-65
			Gallium-67 +
			Arsenic-74
			Arsenic-76
			Selenium-75
			Bromine-82
			Rubidium-81 +
			Rubidium-86
			Strontium-85
			Yttrium-87 +
			Yttrium-90
			Molybdenum-99
			Tin-113
			Tellurium-132
			Iodine-123 +
			Iodine-132
			Caesium-129 +
			Caesium-131
			Promethium-147
			Gold-198
			Mercury-197
			Mercury-203
			Bismuth-206

+ Classification based on NRPB calculations.

P Parent in radioisotope generator.

S Normally used only as a sealed source.

This classification conforms with Schedule 3 of the Ionising Radiations (Unsealed Radioactive Substances) Regulations, 1968.<sup>4</sup> It derives from the Technical Reports Series No. 15 – A Basic Toxicity Classification of Radionuclides<sup>38</sup>, and is quoted in ICRP Publication 5, Handling and Disposal of Radioactive Materials in Hospitals and Medical Research Establishments<sup>19</sup>.

**Table 2**  
**GRADE OF LABORATORY REQUIRED FOR VARIOUS ACTIVITIES  
 OF RADIONUCLIDES OF VARIOUS TOXICITIES**

Classification	Grade of laboratory required for unsealed radionuclides at levels of activity specified below		
	C	B	A
High toxicity (Class 1)	<10 $\mu$ Ci	10 $\mu$ Ci – 1 mCi	>1 mCi
Medium toxicity			
Upper Sub-Group A (Class 2)	<1 mCi	1 mCi – 100 mCi	>100 mCi
Medium toxicity			
Lower Sub-Group B (Class 3)	<100 mCi	100 mCi – 10 Ci	>10 Ci
Low toxicity (Class 4)	<10 Ci	10 Ci – 1000 Ci	>1000 Ci

Modifying factors to be applied to the above activities, according to the complexity of the procedure to be followed

<i>Procedure</i>	<i>Modifying factor</i>
Storage (stock solutions)	$\times 100$
Simple wet operations	$\times 10$
Normal chemical operations	$\times 1$
Complex wet operations with risks of spills	$\times 0.1$
Simple dry operations	
Dry and dusty operations	$\times 0.01$

#### **6.4 General procedures in laboratories and radioisotope departments**

**6.4.1** Each institution must draw up its own detailed local rules for handling unsealed radioactive substances which must be supplemented by careful training of staff at all levels. Major changes in procedures and new procedures must be approved from the point of view of radiological protection by the Radiological Safety Officer of the relevant department and should be tried out by dummy runs, with or without radioactive substances.

**6.4.2** A system must be provided for checking and recording the activity and identity of unsealed radioactive substances before administration to patients (see 6.2.12.vi). Equipment used for this purpose must be calibrated at regular intervals with standard sources. The terms millicurie and microcurie should be written out in full to avoid mistakes.

**6.4.3** Working procedures should be designed to minimize the spread of contamination from the working area, not only in the interests of the safety of persons but also to prevent interference with measurements of radioactivity. For this reason, all dispensing of

radioactive substances should be done in a fume cupboard or glove box especially when particulates or aerosols are involved (see Section 6.2.5.ii).

**6.4.4** Because of the danger of direct transfer of radioactive substances into the body, eating, drinking, smoking, and the application of cosmetics must be forbidden in laboratories using unsealed radio-nuclides. A drinking fountain, however, is admissible.

**6.4.5** Laboratory coats (or protective gowns), preferably reserved specifically for work with radioactive substances, and surgical or similar gloves must be worn for all procedures involving dispensing of radioactive substances and their administration to patients. In addition, especially for work with higher activities, overshoes should be worn. Gloves used for manipulating radioactive substances must not be used outside the active laboratory. The method of putting on and removing gloves should be based on the surgical technique so as to avoid transferring activity to the hands or to the inner surfaces of the gloves. Contaminated gloves should be washed before they are taken off. Regular systematic monitoring of the hands and gloves should be carried out.

**6.4.6** When equipment is provided specifically for the safe handling of unsealed radioactive substances, it must be used. Such equipment should not be moved from the working area in which it is used. The operation by mouth of pipettes and wash-bottles must be forbidden.

**6.4.7** The working area must be kept thoroughly clean and tidy. Cleaning methods (including those for the floors) should be chosen so as to avoid raising dust.

**6.4.8** Specialized equipment for handling radioactive substances must be routinely serviced and protective clothing, especially gloves, must be routinely examined so that faulty items can be rejected when defects occur.

## **6.5 Design of wards**

**6.5.1** Patients undergoing treatment with therapeutic activities of unsealed radioactive substances should not be placed in general wards in which there are patients whose treatment does not involve such therapy. Instead they should be placed in specially designed wards, which preferably should have only one or two beds; where there are two or more beds, these should be arranged so that there is not less than 2.5 metres between centres.

**6.5.2** Patients undergoing treatment should be provided with a toilet and bathroom in the same suite for their exclusive use.

**6.5.3** When hospitals consistently use a wide range of unsealed radioactive substances for diagnostic purposes, wards should be set apart for this work in the interests of good technique.

**6.5.4** Floors, walls, and ceilings should be covered with smooth, continuous, and non-absorbent surfaces which can be easily cleaned. Floor coverings (e.g. linoleum or PVC) should be easily removable if necessary; coverings should be used in sheet rather than tile form in order to reduce the number of joints. Surface finishes (e.g. wax polish) for floor coverings should be removable for decontamination purposes. Some proprietary epoxyresin coatings are easily de-contaminated and provide very satisfactory surface coverings when applied in sufficient thickness on to a firm base. The walls should be finished with a good hard-gloss paint. (For suitable materials for use in radioactive areas, see British Standard BS 4247, Part 2<sup>44</sup>).

**6.5.5** When it is necessary to collect excreta for clinical reasons there should be a storage area, not necessarily shielded, where low-activity samples of urine and faeces can be kept temporarily and where reserve containers are available. A shielded storage area should similarly be provided for the temporary storage of high-activity samples of urine and faeces. Separate bins should be provided for the temporary storage of linen and waste contaminated with radioactive substances. The storage areas and bins should be near the ward and clearly marked, using the recognized symbol (see Appendix F).

## **6.6 General procedures in wards**

**6.6.1** Local rules must be prepared by the Radiological Protection Adviser, in consultation with the Radiological Safety Committee and the Chief Nursing Officer. These rules should be issued to ward sisters and charge nurses and should include instruction sheets prepared for each new technique involving radioactive substances. Where only a few patients are involved, each containing less than 10 microcuries, no special safety precautions in the wards and clinics are necessary. However, even where there is no health hazard, it will be necessary to prevent the spread of contamination for technical reasons and local rules will still be needed for this purpose. When large activities of radioactive substances are used, the instructions should indicate any limitations of the time which ward staff and visitors may spend in the proximity of a patient. It must be impressed upon the staff that nursing procedures which are not urgent should be postponed as long as possible to take full advantage of the reduction of activity by decay and excretion and that there should be only the minimum handling of contaminated bed linen, clothing, towels, china, etc.

**6.6.2** The local rules for the protection of persons in proximity to patients undergoing treatment with unsealed radioactive substances

should be based on the following requirements:

- i Beds in which there are patients undergoing treatment with radioactive substances must have a notice using the standard symbol (see Appendix F) indicating the fact. The notice should give details of the nature and activity of the radioactive substances, the time and date of administration, and any relevant nursing instructions.
- ii The Radiological Safety Officer of the relevant department must measure or otherwise estimate the maximum gamma-ray exposure-rate at a distance of 1 metre from each patient undergoing treatment. If this exposure-rate exceeds  $5 \text{ mR h}^{-1}$ , the notice must in addition indicate that an external radiation hazard exists and the Radiological Safety Officer must give instructions regarding the daily time allowable for nursing procedures and visitors.
- iii It may be necessary to reallocate duties for staff who are confirmed to be pregnant and also to exclude visitors who may be pregnant.
- iv Patients undergoing treatment with radioactive substances must not be permitted to leave the ward suite or treatment room without the approval of the appropriate medical officer. (Rules for patients leaving a hospital after administration of radioactive substances are given in Section 8.)
- v During and following administration of unsealed radionuclides for therapeutic purposes (including external application of materials such as thorium-X), protective gowns and gloves must be worn when handling the patient, his excreta, any contaminated clothing, bed linen, or other articles.
- vi Whenever possible, patients undergoing treatment with radioactive substances should use the toilets provided for the disposal of radioactive urine and faeces. Where a bedpan or urine bottle is provided for a patient, it should be kept for that patient's exclusive use.

**6.6.3** For procedures which are unusually hazardous, the Radiological Protection Adviser should issue special rules and the Radiological Safety Officer of the relevant department should supervise their implementation.

**6.6.4** Crockery and cutlery may become contaminated by the patients undergoing therapy with unsealed radioactive substances. The instruction sheets (see Section 6.6.1) should specify washing up procedures (e.g. by the patient in his or her room where possible) and any necessary segregation of utensils for such patients.

**6.6.5** Apart from protective clothing worn routinely (see Section 6.6.2.v) a separate supply including gloves, gowns, and boots or over-shoes should be set aside for use only in emergencies involving radioactive substances (see Section 6.9).

**6.6.6** Radiation-monitoring equipment must be readily available.

## **6.7 Monitoring of laboratories and working areas**

**6.7.1** Wards, operating theatres, clinics, and laboratories in which work with unsealed radioactive substances is undertaken must be monitored both for external radiation and for surface contamination, on a regular and systematic basis. Adjacent rooms and corridors must also be monitored periodically. The purpose of such monitoring is to establish the adequacy, from the point of view of radiological protection of current working methods and to provide experience in the light of which new techniques may be safely introduced. Monitoring results must be properly recorded for future reference.

**6.7.2** Maximum permissible doses and derived working limits for surface contamination are given in Appendices B and D respectively.

**6.7.3** Monitoring for external beta and gamma-radiation must be instituted whenever work is undertaken with unsealed radioactive substances having an activity greater than 1 millicurie.

**6.7.4** The most suitable instruments for this purpose are portable battery-operated exposure-rate meters. For the measurement of gamma-radiation these may be of the ionization chamber, GM counter, or scintillation detector type. Some ionization chamber types of instrument are suitable for the measurement of both beta and gamma-radiation. The instruments should be capable of measuring exposure-rates from about  $1 \text{ mR h}^{-1}$  upwards. When highly active gamma-ray sources are being manipulated, the provision of instruments that give an aural or visual alarm or both of the presence of high exposure-rates should be considered.

**6.7.5** The extent of the contamination monitoring necessary will depend upon the activity and type of radioactive substances involved and on the technical procedures being used (see Tables 1 and 2 of this Section [pages 47 and 48]). Such monitoring is important for the avoidance of health hazards and to prevent errors in technical measurements resulting from the contamination of low activity samples. Monitoring for contamination involves the following:

- i All working surfaces and the floor of the laboratory or ward must be regularly and systematically monitored for contamination. Surveys of similar surfaces in adjacent rooms and corridors must be carried out as necessary. Equipment

and other items should be monitored while situated in, and on removal from, active areas. Direct monitoring should be the rule but, where this is not practicable, wipe testing should be used.

- ii Clothing, including shoes, of staff working in active areas must be monitored, particularly when leaving the active area. To encourage regular use, a monitoring instrument should be placed near the exit from the laboratory.
- iii Staff working in active areas must ensure that their hands are regularly monitored after work and before eating, drinking, smoking, or the application of cosmetics. An instrument for monitoring the hands should be available where the hands are washed. This monitoring should extend to other skin areas, e.g. the face, if there is any reason to suspect that these areas may have become contaminated. Care must be exercised in the measurement of low levels of skin contamination since, with some instruments, the contamination can only be satisfactorily measured if the levels of background radiation are commensurately low.

**6.7.6** A wide variety of detector probes in association with battery or mains-operated ratemeters is available for contamination monitoring; the types most suitable for any particular application will depend upon local circumstances.

**6.7.7** Where thorium-X is used, the Radiological Protection Adviser should be consulted with regard to the appropriate method for monitoring contamination by measurements of the beta-emitting decay products.

**6.7.8** Contamination monitoring for tritium is particularly difficult because of the very low energy of the emitted beta-particles. The radiotoxicity of tritium, however, is very low and good laboratory practice will usually reduce the need for monitoring to occasional measurements where activities of the order of up to a few tens of millicuries are routinely manipulated. Urine analysis is the most reliable guide in contamination control of tritium. Systematic urine analysis should be undertaken if regular and significant exposure to tritium is unavoidable.

**6.7.9** Under normal working conditions with diagnostic or therapeutic activities of unsealed radioactive substances air monitoring is not necessary. In the event of an emergency involving a serious spill (see Section 6.9) those concerned with the cleaning up procedures should if necessary wear well-fitting respirators or breathing apparatus appropriate to the radioactivity being handled and approved by the

radiological safety committee, so that even under these conditions air monitoring can be avoided.

**6.7.10** Appendix N gives sources of information about monitoring instruments.

## **6.8 Decontamination procedures**

**6.8.1** Persons working with radioactive substances should wash their hands thoroughly with mild soap and water before leaving working areas and especially before eating, drinking, smoking, or the application of cosmetics. Particular attention should be paid to cleaning the fingernails. After washing, the hands should be checked with a radiation monitoring instrument. The derived working limits for surface contamination of the hands and of other parts of the body are given in Appendix D.

**6.8.2** If washing the contaminated skin with soap and water fails to reduce the contamination to the required level, an appropriate detergent should be tried. If this fails, treatment with a saturated solution of potassium permanganate followed by decolourization with 5 per cent sodium bisulphite may be used (potassium permanganate should not be applied to contaminated hair as there is a risk of causing temporary change of hair colour). Chemical treatment should not be applied too vigorously as the skin may become porous. Even when the contamination has not been reduced to the required level, none of these procedures should be carried on to the stage of injuring the skin.

**6.8.3** When high level contamination of parts of the body, other than the hands, is suspected or when the procedures described above are ineffective, the Radiological Safety Officer of the relevant department and the Head of the Department should be notified at once. Special care needs to be taken in the decontamination of areas near the eyes and in preventing spread of contamination to other parts of the body (e.g. showerbaths should only be taken after the major areas of contamination have been cleansed).

**6.8.4** If the skin is broken or a wound is sustained in conditions where there is a risk of radioactive contamination, the injury should be irrigated immediately with tap water. As soon as the first aid measures have been taken, the person should report to the Supervisory Medical Officer for further treatment, including decontamination if necessary. In such cases, details of the incident must be recorded on the radiation dose record.

**6.8.5** A summary in tabular form of the above procedures should be prepared for handy use in case of accidents or spills (see Section 6.9).

**6.8.6** The derived working limits of surface contamination of benches and floors of working areas and of glassware and laboratory equipment are given in Appendix D.

**6.8.7** Paintwork should be cleaned with detergent and water or, in severe cases of long-lived contamination, removed with a paint remover. Polished linoleum and epoxyresin floor coverings should be cleaned with detergent and water. Linoleum should preferably be sealed with a varnish, e.g. polyurethane, and water emulsion polish used to maintain it. For short-lived radionuclides, if activity still remains, the surface should be suitably covered until the radioactivity has decayed to a sufficiently low level; sisalcraft paper is very suitable for this purpose. In the case of high levels of contamination with long-lived radionuclides, it may be necessary to remove and replace the floor surface (see Section 6.5.4).

**6.8.8** Glassware should preferably be cleaned with an alkaline detergent immediately after use. If the contamination has been allowed to dry, the glassware should be marked and segregated for special attention when cleaning. Glassware and porcelain can usually be cleaned by any of the normal chemical agents, of which chromic-sulphuric acid solution (which should be handled with care) is probably the most effective. Other cleaning agents are ammonium citrate and other chelating agents (such as EDTA), or various proprietary solutions. The solutions used for cleaning must not be returned to the stock bottle.

**6.8.9** Dilute nitric acid can be used to clean plastic, since it will usually be effective without damaging the material. Care should be taken to avoid the use of ketonic solvents and certain chlorinated hydrocarbons.

**6.8.10** All metal tools, trays, sinks, and equipment should be monitored to detect possible contamination. They may be cleaned by washing with a heavy-duty detergent of the type used for laundering, followed if necessary by inhibited phosphoric acid, or by dilute sulphuric acid, or by mixtures of citrates with EDTA or ammonium oxalate. For stainless steel, hydrochloric acid must be avoided as it is likely to corrode the equipment. When other procedures fail with stainless steel, a mixture of 6 per cent nitric acid with 1 per cent sodium fluoride may be used. In all cases, the cleaning agent should be used only for a minimum time, otherwise corrosion of the equipment is likely to occur thus causing greater difficulty in future decontamination. Stubborn contamination may often be removed by the use of a slightly abrasive polish but only at the expense of some damage to the surface.

**6.8.11** Decontamination procedures may not reduce the activity of equipment and glassware to acceptable levels. In this case, if long-lived radionuclides are concerned, the items must be regarded as radioactive waste. For short-lived radionuclides, it may be feasible to store certain articles until the radioactivity decays sufficiently. However, in either event, care must be taken to ensure that the proposed action does not contravene the regulations for the storage or disposal of radioactive substances (see Section 10).

**6.8.12** Protective and personal clothing of staff, and clothing and bedding of hospital patients who are being treated with radioactive substances should be monitored at regular intervals according to the radiation hazard involved. Any article that is known to be, or suspected of being, excessively contaminated must be placed in a container provided for such articles. The permissible levels of contamination are given in Appendix D.

**6.8.13** Contaminated clothing or bedding must not be sent to public laundries unless the activities, averaged over an area not exceeding  $300\text{ cm}^2$ , are everywhere below the derived working limits given in Appendix D.

**6.8.14** Articles contaminated with short-lived radionuclides at limits above those given in Appendix D should be stored in impermeable bags until the level has fallen to an acceptable value. Care must be taken to prevent airborne contamination during the movement of such contaminated clothing and bedding. When storage is not practicable but special laundering facilities are available in a hospital, contaminated garments or bedding with an activity above the derived working limits should be given a series of hot rinses in commercial laundry detergent, alternating with rinses in clear water. If the contamination persists, the article should be washed in a hot solution of 1.5 per cent citric acid followed by a series of cold rinses. An automatic washing machine is very useful for this purpose. Clothing which cannot be laundered satisfactorily or be held for storage must be regarded as radioactive waste.

## **6.9 Emergency procedures**

**6.9.1** Experience has shown that most incidents involving spills of radioactive substances in hospitals do not warrant any drastic emergency action but require only simple remedial action by local staff, often as part of their routine procedures for the control of the spread of contamination. Nevertheless, a more serious incident could possibly occur and some preparation to anticipate the event is necessary. In the present context, an incident is considered to require specialized action if it involves the dispersal of an activity of radioactive substances which is more than the appropriate minimum

activity given for Grade B laboratories in Table 2 of this Section (page 48), if wet, and more than one-tenth of this activity if dry. In such a case, prearranged procedures must be instituted as soon as possible and the Radiological Protection Adviser must be informed.

**6.9.2** In any incident, the first concern must be the protection of any persons involved (whether patients or staff) and the treatment of any serious injury. The second concern is to confine the contamination as far as possible to the area originally affected. Decontamination of personnel must also take priority over any plan for decontamination of working areas, although immediate arrangements must be made to restrict the spread of contamination.

**6.9.3** Local rules must be drawn up to specify:

- i The persons to be notified of any incident involving the dispersal of radioactive substances at the activities indicated in Section 6.9.1. Note also the possibility of action being required under Section 2.3.8.
- ii The instructions to staff (including nurses) on any immediate action to be taken.
- iii The location of equipment for dealing with incidents.

The rules must be read and understood by all persons who may be concerned. They should be reviewed periodically and revised as necessary.

**6.9.4** Where it is envisaged that a serious incident with radioactive substances could arise, practical exercises should be held to test the effectiveness of the arrangements and to ensure that all persons concerned know what action to take.

**6.9.5** Notices must be posted in or near every active area showing:

- i The system for warning persons in the vicinity.
- ii The system for contacting the Radiological Safety Officer of the department, to whom the emergency must be notified immediately.
- iii The location and method of use of emergency equipment for dealing with the incident.

**6.9.6** In the event of a fire involving radioactive substances, the local rules referred to in Section 2.8.3 must be put into effect. These rules must indicate which uses of radioactive substances require special precautions to be taken in fire fighting and subsequently.

**6.9.7** The best course of action in an incident depends very much on local circumstances. Until an appropriate plan has been worked out by the Radiological Safety Officer of the relevant department for

the particular incident, only the minimum immediate action should be taken; for example:

- i Persons in the immediate vicinity should be warned of the incident.
- ii Any assistance called for by particular local circumstances should be rendered.
- iii Radioactive substances on the skin should be thoroughly flushed away with tap water (see Section 6.8.3).
- iv Protective and, if possible, other outer clothing which is contaminated with radioactive substances should be removed and left in the affected area.
- v All functioning laboratory apparatus should be made safe; other laboratory services and ventilation, except lighting, should be switched off and all doors and windows should be closed to restrict the spread of contamination by draughts and to restrict access. However, where radioactive gas or vapour, e.g. tritiated water vapour, is dispersed, the mechanical ventilation should be left on and, according to discretion, the doors and windows should be opened.
- vi If it is necessary to evacuate all non-essential persons (whether staff or patients) an attempt should be made to ensure that contamination, particularly on shoes or clothing, is not carried to other unaffected areas. If contaminated persons are evacuated, they should be monitored and measures to reduce surface contamination should be taken as soon as possible.
- vii Persons entering the affected area to carry out emergency procedures should wear protective clothing and equipment.

**6.9.8** Entry to the affected area must be restricted until all the appropriate action has been taken to clear the contamination from the area and radiation surveys have satisfied the Radiological Safety Officer of the relevant department that the area may be reoccupied.

**6.9.9** In the event of incidents involving therapeutic activities of radioactive substances, the need for tests to determine the activity which has entered the body should be considered (see Section 2.4.4) and an estimate should be made of the dose from internal and external radiation received by persons involved in the incident. The Controlling Authority must arrange for any special medical examinations of the affected persons which the Supervisory Medical Officer recommends.

**6.9.10** The Radiological Protection Adviser must carry out an investigation of any incident involving specialized action as defined

in Section 6.9.1, keep a written record, and make a report to the Controlling Authority with recommendations for avoiding recurrence.

**6.9.11** Equipment should be kept available for use in an emergency in any departments where activities are used in excess of those permitted in Grade C laboratories for Classes 1, 2, and 3 nuclides and in excess of 100 millicuries for Class 4 nuclides. The essential items must depend on the type of work being carried out, but consideration should be given to the inclusion of the following:

- i Overshoes, protective clothing (including caps) and respirators or breathing apparatus.
- ii Decontamination materials for the affected area, including absorbent material for wiping up spills.
- iii Decontamination materials for persons.
- iv Equipment for preventing entry into the affected area, including warning notices.
- v Equipment for the handling, temporary storage, and disposal of contaminated articles.
- vi Portable monitoring equipment, including personal monitoring devices such as pocket dose-meters and film badges (drawn from current stocks as necessary).
- vii Sundry items such as adhesive tape, labels, torch, notebook and pencils, and simple first-aid equipment.

In all departments where a decontamination problem could arise, it is useful to keep a selection of the emergency equipment in a clearly labelled suitcase or similar portable container which is in a visible and readily accessible site.

# 7 PROTECTION OF THE PATIENT

## 7.1 Introduction

**7.1.1** This section re-emphasizes those aspects of the protection of the patient which are of particular concern to all other clinicians as well as to radiologists, and which should be taken into account by clinicians requesting an examination or treatment. Precautions which are the particular concern of radiologists, radiotherapists, radiographers, and those responsible for treatment and investigation employing radionuclides are those dealt with in Sections 3, 4, 5, and 6.

**7.1.2** Detailed surveys of radiological procedures were carried out under the auspices of the Adrian Committee on Radiological Hazards to Patients<sup>55</sup>. Typical doses to the skin, bone-marrow, and gonads are given in the Handbook of Radiological Protection, Part 1: Data<sup>45</sup>. Organ doses from various investigations with radionuclides are also included in the Handbook and in ICRP Publication 17<sup>30</sup>.

**7.1.3** Patients exposed to radiation for diagnostic or therapeutic purposes may be subject to some personal hazard, and the direct or indirect irradiation of their gonads may constitute a hazard to future generations (see also Section 7.3.2 for examinations of women known to be pregnant). Consequently it is important that only those radiological examinations and treatments that are necessary should be requested.

**7.1.4** In carefully selected diagnostic procedures, if proper protective measures are employed and if the irradiation of the patient is kept to the lowest limit consistent with the clinical needs of each case, the risks either to the individual or to successive generations can be regarded as justifiable in the light of the benefits to be obtained.

**7.1.5** In therapeutic as compared with diagnostic procedures considerably larger doses of radiation are necessarily given. Nevertheless every effort must be made to reduce the dose to parts not being treated.

## 7.2 General

**7.2.1** The clinician requesting the examination or investigation must satisfy himself that it is necessary. Unnecessary examinations are sometimes requested due to failure to ascertain whether there are records of previous radiological examinations or investigations with radionuclides, details of which should be inserted in the patient's record. (For women of reproductive capacity see also Section 7.3.1).

**7.2.2** It is the responsibility of the clinician requesting an examination to state the clinical indications, the provisional diagnosis, and the information required.

**7.2.3** If there is any doubt about the advisability of carrying out the investigation or about the nature of the investigation required, the matter should be resolved by consultation between the medical officers responsible respectively for the clinical and radiological care of the patient. Regular organized case discussion sessions attended by radiologists and other clinicians give opportunity for critical estimation of the likely value of a proposed X-ray examination or diagnostic radionuclide test.

**7.2.4** To reduce the necessity for repeat radiological examinations involving abdominal investigations, strict attention should be paid to adequate preparation of the patient.

**7.2.5** Fluoroscopy should not be requested if the same information can be obtained by radiography. It should not be used for locating metallic foreign bodies at operations since electronic metal-locating equipment is now available.

### **7.3 Pregnancy**

**7.3.1** In all women of reproductive capacity the clinician requesting the examination should consider the possibility of an early stage of pregnancy. The date of the last menstrual period should be entered on the request form and it is the responsibility of the clinician requesting the examination to ascertain this. To reduce the likelihood of irradiation of a pregnancy, examinations involving the lower abdomen should, if practicable, be carried out within 10 days following the first day of the menstrual period.

**7.3.2** Special precautions should be adopted in the radiography of women known to be pregnant. Only absolutely essential examination should be carried out during pregnancy and particular care should be taken to minimize irradiation of the foetus.

**7.3.3** Mass miniature techniques should not be requested for chest examinations of pregnant women. Full-sized films with strict limitation of field size should be used for these examinations.

### **7.4 Availability of previous films**

**7.4.1** To reduce unnecessary examinations, administrative arrangements must be made for the ready availability of previous films and for the transfer on request of films or copies from one hospital to another.

### **7.5 Radiotherapy**

**7.5.1** Any history of previous radiotherapy should be ascertained before a new course of treatment is requested. Permanent records of all radiotherapy must be maintained and be readily available for transfer from one hospital to another.

# 8 PATIENTS LEAVING A HOSPITAL AFTER ADMINISTRATION OF RADIOACTIVE SUBSTANCES

## 8.1 Introduction

**8.1.1** This section deals with the conditions under which both in-patients and out-patients who are undergoing treatment with radioactive substances may be allowed to leave hospital to return to their home. It is intended to give general guidance to radiotherapists, and other clinicians who should use their discretion in regard to individual cases. This section should be read throughout in conjunction with Appendix I.

## 8.2 General considerations

**8.2.1** Such patients may be permitted to leave hospital subject to the following conditions:

- i The residual activities of the radionuclides administered or applied do not exceed the values given in Table I1 nor such lower values as may be decided in the light of the advice given in Appendix I.
- ii The likelihood of a sealed source being lost or of an unsealed radioactive substance leaking from the body is remote.
- iii The patients are given instructions regarding their behaviour, personal activities, and movements during an appropriate ensuing period.

**8.2.2** If the activity on leaving hospital is such that instructions in accordance with Section 8.2.1.iii need to be given to a patient, because the residual activity is greater than one quarter of that shown in Table I1, he must be provided with, and be instructed to carry, a card detailing such instructions and giving the address and telephone number of the hospital and department to be contacted in case of difficulty or accident. A suggested format for such a card is shown in Appendix I. The patient's general practitioner must be informed of the instructions given to the patient on leaving hospital.

**8.2.3** If the activity on leaving hospital is in excess of the values given in Appendix J, the hospital from which the patient is leaving must be prepared to specify, on enquiry, the dates before which, in the event of death, neither a post-mortem examination, nor embalming, nor cremation should take place (see paragraphs 5 and 8 of Appendix J).

### 8.3 Instructions to patients

**8.3.1** The instructions given to patients and detailed on the instruction card should be based on the following considerations, which in general apply to activities at or near the maximum values given in Table I1:

- i Conditions should be specified under which subsequent journeys by public transport may be made.
- ii For a week after leaving hospital, or for as long as levels of radioactivity may be high, particular care should be taken to avoid close contact with other members of the household, especially children and young people. Instructions regarding contact with children are best given personally and should not be detailed on an instruction card.
- iii The patient should not return to work nor visit places of entertainment until an appropriate period of time has elapsed.

If the activities, are substantially less than those given in Table I1, relaxations can be applied.

# 9 STORAGE AND MOVEMENT OF RADIOACTIVE SUBSTANCES

## 9.1 Introduction

**9.1.1** The following recommendations on the storage and movement of radioactive substances have the purpose of ensuring that satisfactory standards of safety are maintained in all establishments using these substances, and although hospitals are specifically referred to, the recommendations apply equally to clinics and private practice. Users of small activities of radioactive substances may not find it necessary to appoint a specific person to be responsible to the Custodian (see Sections 9.2.12 and 9.2.25). In such cases the duties assigned in the Code to these persons will still need to be performed and it will be necessary to establish a procedure and to allocate responsibilities to ensure this.

**9.1.2** All users are reminded of the requirements of the Radioactive Substances Act 1960<sup>2</sup>. The Act requires registration of the keeping and use of radioactive substances and also provides for authorization to accumulate and dispose of radioactive waste. Advice may be obtained from the Radiochemical Inspectorates of the Department of the Environment in England and Wales, The Scottish Development Department, or the Ministry of Health and Social Services for Northern Ireland as appropriate.

## 9.2 Storage and internal movement of radioactive substances

**9.2.1** In each hospital where radioactive substances are used, a Custodian, who may be the Radiological Protection Adviser, must be nominated to be responsible, in consultation with the Radiological Safety Committee of the hospital, for organizing the security during storage and use of all types of radioactive substances and for ensuring that all necessary records are kept.

**9.2.2** Each hospital must be provided with one or more main stores for radioactive substances which can be securely locked. A warning notice of the design illustrated in Appendix F must be displayed where it can easily be read outside the place of storage.

**9.2.3** Full records must be kept of all radioactive substances received, stored, and issued.

**9.2.4** The stores must be maintained in an orderly fashion and must be inspected regularly by the Custodian or by a responsible person nominated by him.

**9.2.5** Stores for radioactive substances must be so sited and designed that such substances can be both stored and transferred to and from

a store without excessive exposure of any person. The protection provided within the stores for sealed sources and unsealed radioactive substances must be such that the person who transfers them to and from the stores does not, in the performance of these duties during any working period, receive more than small fractions of each of the maximum permissible doses (see Appendix B). To minimize exposure of staff resulting from transport of substances, stores should, where practicable, be located near the working areas, e.g. the radium store and laboratory should be near to the radium theatre. Data for the computation of shielding against both beta and gamma-radiations are given in the Handbook of Radiological Protection, Part 1: Data<sup>45</sup>.

**9.2.6** In providing shielding for radioactive substances consideration must be given to the scattered radiation. It is not sufficient to place large activities behind a barrier, no matter how thick, if the radiation scattered round it presents a hazard.

**9.2.7** Where necessary to protect the persons employed from air-borne radioactive substances adequate arrangements must be made for ventilating every store containing these substances to the open air by mechanical means. Fans should be operated continuously while staff are present in the store room and also for a sufficient time before the room is entered. A lockable fume cupboard may be the best place for storing iodine-131 (see Section 6.2.10).

**9.2.8** Attention should be given to the radiation hazards which may arise from stored radioactive substances in the event of fire and flood. The place of storage must be chosen and the store constructed with this in mind. Advice on these matters may be sought from the Chief Fire Officer\* (see Section 2.8).

**9.2.9** Subsidiary protected stores, secure against tampering and theft, must be provided at all sites in the hospital (e.g. laboratories, radium theatre, wards) where radioactive substances may have to be left for any significant period of time when not actually in use. These stores should be large enough to hold appliances carrying sealed sources and containers for radioactive fluids. A warning notice of the design illustrated in Appendix F must be displayed at each store.

**9.2.10** Radioactive substances must be issued from a main store only by a person nominated for this purpose (see Section 9.2.12 and 9.2.25) and thereafter, until their return or disposal, must be at all times in the care of responsible individuals. Local rules should be formulated for each hospital in order to define precisely the responsi-

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\*In Scotland, the Firemaster.

bility of such individuals at each stage of the movement of radioactive substances in the hospital and to other hospitals.

**9.2.11** Radioactive substances should be transported within the hospital only in containers provided for the purpose and distinguished by a label carrying the symbol illustrated in Appendix F. Such containers must be designed:

- i To provide adequate protection for all persons during loading, transport and unloading.
- ii To prevent loss of radioactive substances.
- iii To minimize the risk of spilling unsealed radioactive substances.

Radioactive substances may be moved within the hospital in the packaging as presented for external transport (see Section 9.3 and Appendix K).

**9.2.12** A specific person or persons must be nominated to be directly responsible under the Custodian of Radioactive Substances for the receipt, storage, maintenance and issue of sealed sources; the responsibilities of this person or persons should be defined in the local rules.

**9.2.13** In the main store a number of separate compartments should be provided (for example drawers or slides) so that the total stock of sources can be subdivided into a number of smaller groups. A separate compartment should normally be provided for each different type of source, while a number of compartments should be provided for sources of one type when the number of such sources is considerable. An individual compartment should not normally contain more than 20 sources, or an activity exceeding the gamma-ray equivalent of 100 mg radium-226. Each compartment should be so marked as to permit immediate and certain identification of its contents from the outside.

**9.2.14** Where two or more types of source have a similar appearance a method of discrimination must be adopted, and a check should be made regularly to verify that the sources are correctly identified.

**9.2.15** A sealed sources register must be kept, showing full particulars of all sealed sources having a half-life greater than a few days (e.g. yttrium-90 and gold-198 need not be registered). This register must include all relevant information concerning the radionuclide, its activity on a given date, and the construction, dimensions, and serial numbers (where appropriate) of each type of source. Records of examinations, leakage tests and repairs (see Section 9.2.20) must also be included in the register.

**9.2.16** Records must be kept of all sealed sources received at or issued from the main store. These records must be signed by the person or persons nominated in Section 9.2.12 and must be sufficiently detailed and so arranged that information concerning the precise whereabouts of every sealed source which has been issued, and its expected time of return, is immediately available. A means should also be provided for showing at any time the number of sources of each type actually in the store and available for issue. The possibility of supplementing written records with a convenient visual display system should be considered.

**9.2.17** Whenever sealed sources are transferred from the care of one person to another, the recipient must sign a receipt on a form provided for this purpose. This receipt must state the radioactive nuclide, the approximate activity, the types, the number of sources and the person or department from which they were received.

**9.2.18** At regular and frequent intervals, the Custodian or the person or persons nominated in Section 9.2.12, must undertake an audit to account for every source listed in the sealed sources register. Sources in the store must be counted (without checking serial numbers) except that a previous count may be accepted for a group of sources which have been stored in a sealed container since the previous audit. Sources which have left the store must be covered by a current receipt.

**9.2.19** An annual check audit of all sealed sources must be undertaken by a senior officer nominated by the Controlling Authority.

**9.2.20** Sealed sources must be inspected after use for evidence of damage before being returned to a main store. All such sources must also be regularly examined by a competent person with sufficient frequency to permit the early detection of progressive damage which might lead to the leakage of radioactive substances; records of these examinations must be entered in the sealed sources register (see Section 5.1.8).

**9.2.21** When a sealed source is damaged to an extent which involves, or which might involve, the spilling of radioactive substances, a competent person properly equipped for the purpose must be instructed to recover or remove the radioactive substances. Until this has been done, all practicable measures must be taken to prevent the dispersal of the radioactive substance and for safeguarding all persons involved. These measures may include temporary vacation of contaminated premises. In this connection accidents to radium containers must be treated as serious emergencies (see Section 5.3.2).

**9.2.22** Effective means must be provided to minimize the possibility of loss and subsequent damage of sealed sources, e.g. it should not be

possible for sources which might be mislaid or lost from a patient to reach the refuse incinerator or laundry. Dressings and excreta from patients receiving treatment with sealed sources must not be disposed of until it has been proved that there is no lost source present. All containers such as rubbish bins, soiled dressings bins, laundry baskets, coming from a ward or other area where sealed sources are employed, should be tested for radioactivity with a suitable instrument before the contents are disposed of. A double check can be provided by permanently installing a source alarm in an appropriate doorway or corridor through which outgoing bins, baskets, and food trolleys have to pass.

**9.2.23** Local rules stating the actions to be taken in the event of the loss or suspected loss of a sealed source must be formulated by each Controlling Authority. The following points are important:

- i The Radiological Safety Officer of the relevant department and the person who is responsible in accordance with Section 9.2.10 must be informed without delay. The Radiological Safety Officer should arrange for an immediate search for the lost source to be made by a competent person. The possibility that the lost source might have fallen into a gap in protective material should not be overlooked.
- ii The Radiological Protection Adviser should also be informed.
- iii All means by which the lost source might be moved further astray, should, as far as possible, be eliminated, until the search referred to in Section 9.2.23.i has been carried out. For example, there should be no sweeping of floors, no disturbing of furniture, sinks, sluices or toilets, no movement or disposal of soiled dressings, laundry or dustbins, and minimal movement of staff or patients.
- iv If necessary, assistance should be summoned either from the National Radiological Protection Board or through the National Arrangements for dealing with Incidents involving Radioactivity (NAIR).
- v Pending the search referred to in Section 9.2.23.i any fires which might be involved should not be made up and the ashes should not be disturbed; also no further material should be placed in the hospital incinerator.
- vi Should there be any reason to suspect that the lost source might have become damaged, the possibility of contamination by spilled radioactive substances should be borne in mind. On the earliest indication of such contamination, rigorous precautionary measures, such as those stated in Section 9.2.21 should be instituted at once.

**9.2.24** Sealed sources should be cleaned before being returned to the store so as to minimize subsequent sterilization difficulties. See Section 5.2 regarding the cleaning and sterilizing of small sealed sources.

**9.2.25** In each department in which unsealed radioactive substances are stored there must be a nominated person or persons directly responsible, under the Custodian of Radioactive Substances, for the receipt, storage, maintenance, and issue of unsealed radioactive substances; the responsibilities of this person or persons should be defined in the local rules.

**9.2.26** In an area where unsealed radioactive substances are stored a number of separate compartments should be provided so that the total stock can be subdivided. Normally a separate compartment should be provided for each different radionuclide, while a number of compartments should be provided for each radionuclide when the number of containers is considerable. Whenever possible an individual compartment should not contain an activity exceeding the gamma-ray equivalent of 100 mg radium-226. Each compartment must be so marked as to permit immediate and certain identification of the contents from the outside.

**9.2.27** In each department concerned, the person or persons nominated (see Section 9.2.25) must keep records of all unsealed radioactive substances received and issued. The purpose for which each substance is issued must be recorded and the recipient must give a signed receipt.

**9.2.28** Persons to whose custody unsealed radioactive substances are subsequently transferred must sign a receipt on an approved form.

**9.2.29** The person or persons nominated (see Section 9.2.25) must at regular and frequent intervals inspect the stocks of unsealed radioactive substances in his department. Records must be kept showing all stocks present at the time of each inspection, and of all unsealed radioactive substances disposed of from the store as radioactive waste (see also Section 10.3.2).

**9.2.30** All containers must be clearly labelled, using a system whereby the contents can be readily identified.

**9.2.31** Whenever practicable, fragile containers must be stored inside unbreakable containers.

**9.2.32** The following special precautions concerning the storage of unsealed radioactive substances should be adopted:

- i Active residues even of the activities used in diagnostic investigation must be stored in containers the stoppers of

which will not leak but will allow excess pressure of gas to escape.

- ii Chemically stable solutions containing radioactive substances in excess of 5 millicuries of alpha-activity and 50 millicuries of beta-activity must be stored in properly vented containers. These activities may be expected to produce about 1 millilitre per month of gas at standard temperature and pressure from radiation decomposition of water.
- iii Chemically unstable solutions containing radioactive substances e.g. nitric acid, or other oxidising solutions containing traces of organic material, peroxides, chlorates, etc., must be stored in vented containers.
- iv Special care should be taken in opening containers of radioactive substances which have been long in store to minimize the danger from bursting or frothing.
- v Highly alpha-active solutions should not be left in thin glass vessels as the glass is liable to weaken under irradiation. It is not possible to state a concentration at which this becomes serious because the main danger is from dry deposits above the liquid surface. It should be borne in mind at concentrations of the order of 1 millicurie per millilitre.

**9.2.33** Vessels holding radioactive substances of activities greater than those used in diagnostic investigations must be moved within the hospital in containers meeting the requirements of 9.2.11.

**9.2.34** When a patient undergoing treatment with unsealed radioactive substances is moved within the hospital, containers as described in Section 9.2.11 should be provided for the transport of any bottles containing radioactive urine.

**9.2.35** Any spills during storage or transport of radioactive substances or movement of the patient must be dealt with immediately as recommended in Section 6.9.

### **9.3 Transport of radioactive substances outside hospitals**

**9.3.1** The transport of radioactive substances outside hospital premises must be in accordance with the current regulations or codes of practice relating to the various means of transport used, and it is the responsibility of the Radiological Safety Officer of the department issuing the radioactive substances to ensure this.

**9.3.2** Road<sup>11,12</sup>, rail<sup>15</sup>, sea<sup>13</sup>, and air<sup>14</sup> transport regulations are in force. Port Authorities have byelaws which invariably include provisions for dealing with radioactive substances. These byelaws are usually based upon the Department of the Environment's Code of

Practice for Conveyance through Ports of Radioactive Materials<sup>47</sup>. Regulations for all modes of transport, together with associated codes of practice, are based upon the International Atomic Energy Agency Transport Regulations<sup>34</sup>. The Radiological Safety Officer of the relevant department should familiarize himself with the regulations; some general information is given in Appendix K.

# 10 DISPOSAL OF RADIOACTIVE WASTE

## 10.1 Explanation of legal implications

**10.1.1** The Radioactive Substances Act, 1960<sup>2</sup>, requires in general that persons who keep or use radioactive substances on any premises which are used for the purposes of an undertaking must register with the Secretary of State for the Environment, (in Scotland and Wales, the Secretary of State and in Northern Ireland, the Ministry of Health and Social Services). National Health Service hospitals are specifically exempted from this provision,\* but arrangements have been made to ensure that these Ministers are kept informed of all such hospitals which keep or use radioactive substances. The exemption does not extend to other hospitals or premises.

**10.1.2** The Act requires also that authorizations must be obtained from these Ministers for the accumulation or disposal of radioactive waste. It is an offence to accumulate or to dispose of waste if an authorization has not been given, or if one has been given, otherwise than in accordance with the conditions specified in it.

**10.1.3** Unless the accumulation or disposal has been exempted by order made under the Act, National Health Service hospitals must apply for an authorization to the appropriate Minister, from whom advice on how to make the application can be obtained. Disposals of minor activities of radioactive waste, including thorium-X, have, subject to certain conditions, been exempted by orders from the authorization requirements (see Section 10.3).

**10.1.4** It will be the duty of the Controlling Authority to ensure that an authorization is obtained, to specify local rules to ensure that its conditions are observed, and to check periodically that the rules are being followed.

## 10.2 General guidance

**10.2.1** The general government policy governing disposals has been propounded in the White Paper 'The Control of Radioactive Wastes'<sup>56</sup>. Where it is safe and practicable to do so, local methods for disposal of ordinary waste should be used, since they are usually inexpensive and often give adequate dilution or dispersal. Where this is not possible, special disposal arrangements are available which utilize the disposal facilities of the United Kingdom Atomic Energy Authority. Details of these arrangements may be obtained from the Department of the Environment, the Scottish Development Depart-

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\*The corresponding hospitals in Northern Ireland are not exempted.

ment, the Ministry of Health and Social Services for Northern Ireland, or the Welsh Office. The White Paper gives some guidance on the levels of activity which can in general be disposed of with ordinary waste. The authorizations and the conditions imposed by the authorizations will be based on this general guidance but they will have regard to the local conditions, which may affect permissible levels. Local conditions vary so widely that general conditions may frequently be modified.

**10.2.2** It is convenient to recognize the following types of radioactive waste which may occur in hospitals:

- i Sealed sources.
- ii Excreta from patients treated with radionuclides.
- iii Unwanted solutions of radionuclides intended for therapeutic use.
- iv Normal low-level liquid waste, e.g. from washing of apparatus or liquid scintillation-counting residues.
- v Normal low-level solid waste, e.g. paper, glass.
- vi Waste from spills and decontamination.
- vii Gases.

**10.2.3** Waste sealed sources are easily contained and managed but may present a hazard if set aside unlabelled and forgotten. They should be clearly labelled and stored until by decay the activity is reduced to a level which permits disposal with ordinary waste, or they should be disposed of at once by the special disposal service. It is important that a decision should be taken as soon as they are recognized as waste and action taken to implement the decision with reasonable speed.

**10.2.4** The collection of radioactive excreta from patients and its storage will cause the irradiation of nurses and other hospital workers and increase the risk of spills. The nature of this material makes its storage undesirable in hospitals, unless good reasons for storage can be adduced. In most cases, disposal to a sewerage system will afford sufficient dilution to make irradiation of sewer workers and sewage disposal workers negligible. Since the sewerage from most of the big cities in the United Kingdom drains to the sea, to estuaries, and to rivers not used as drinking water supplies, there will not usually be any significant hazard. Accordingly, at the present levels of use of the relatively short-lived radionuclides now employed in hospitals, excreta from patients should be disposed of to the sewer. A convenient number of water closets should be reserved for these patients and activity levels should be checked periodically. The drains serving the closets should be regarded as drains from a radioactive

laboratory and if repairs are necessary, they should be done under the supervision of the Radiological Safety Officer and measurements of radiation levels should be made as the drain is opened up.

**10.2.5** It may occasionally happen that relatively large activities, for example, of iodine-131 and gold-198, are left over or unused. If the solutions are in a readily manageable form and of sufficiently short half-life to render storage for decay convenient, they should be stored until their activity permits disposal to the sewer.

**10.2.6** The liquid waste normally resulting from the simple operations involved in dispensing and making up solutions for hospital use is of low activity and suitable for disposal to the sewer.

**10.2.7** The solid waste normally occurring, comprising paper tissues, swabs, glassware, and similar materials, is of low activity, usually only a few microcuries, and suitable for disposal with ordinary refuse. Occasionally more active items arise, e.g. bed linen from incontinent patients and unwanted or broken applicators. Care should be taken to segregate contaminated clothing and linen for treatment as indicated in Section 6.8.12. Applicators should be stored until decay permits disposal in accordance with the authorization or be disposed of by the special disposal service.

**10.2.8** The nature and consequences of spills and accidents can hardly be foreseen and useful general rules to deal with the radioactive waste problems that result are not readily formulated. So far as is practicable, consistent with the safety of the staff involved and the urgency of the decontamination measures, consideration should be given to the radioactive waste resulting from the cleaning-up operations. Heavily contaminated swabs and other items should be set aside for storage or special disposal.

**10.2.9** Generally the only significant gaseous wastes resulting from normal hospital use of radioactive substances are exhausts from stores, especially radium stores, and from fume cupboards and emissions from incinerators. It is important that the points of release to the atmosphere should be carefully sited (see Section 6.2.10 and 6.2.11). Radiation and contamination levels near them should be checked periodically by the Radiological Safety Officer of the relevant department.

**10.2.10** In some hospitals research work may create wastes outside the categories listed in Section 10.2.2. Often the research may involve only tracer levels of radionuclides and normal methods of refuse disposal may be adequate, e.g. incineration of combustible waste contaminated by carbon-14, tritium, or iodine-131, with ordinary

refuse may provide conditions for adequate dispersal of the radio-nuclides in the atmosphere. Incineration of refuse containing non-volatile radionuclides concentrates the activity in the ash, and ash of undesirably high activity in a not easily controllable state may be produced. For wastes which cannot be disposed of by normal methods the special disposal service should be used (see Section 10.2.1).

### 10.3 Exemption Orders

**10.3.1** Summaries of the Exemption Orders which have been made under the Radioactive Substances Act, 1960<sup>2</sup>, relating to minor discharges of radioactive wastes from hospitals and to the use of thorium-X are given below.

**10.3.2** Under the Hospitals' Waste Exemption Orders<sup>5,6,7</sup>, radioactive waste arising on the premises of a hospital from the medical treatment of human beings, being waste containing no alpha-emitters and no strontium-90, may be disposed of without authorization:

- i By means of the local authority refuse disposal service or to a tip used normally for inactive refuse provided that in any container at the time of disposal the activity is not greater than 10 microcuries, that the activity of any article is not greater than 1 microcurie, and that the volume of refuse is not less than 3 cubic feet ( $0.1\text{ m}^3$ ).
- ii By burning on the premises, provided the activity burnt is not greater than 30 microcuries in any day.
- iii By discharge to the foul water drainage system provided that in any four consecutive weeks the activity does not exceed 10 millicuries if the system connects to a public sewer or 2 millicuries if it does not.

It is a condition of exemption that records of the activities disposed of are kept; the activities may be estimated in any generally accepted manner.

**10.3.3** The Thorium-X Exemption Orders<sup>8,9,10</sup> provide that radioactive waste arising on the premises of a hospital from the use of ointments or solutions of thorium-X for the medical treatment of human beings may be disposed of without authorization:

- i By means of the local authority refuse disposal service or to a tip used normally for inactive refuse provided the activity does not exceed 10 microcuries of thorium-X in any week.
- ii By burning on the premises without condition (but the disposal of incinerator ash is subject to the previous limit).

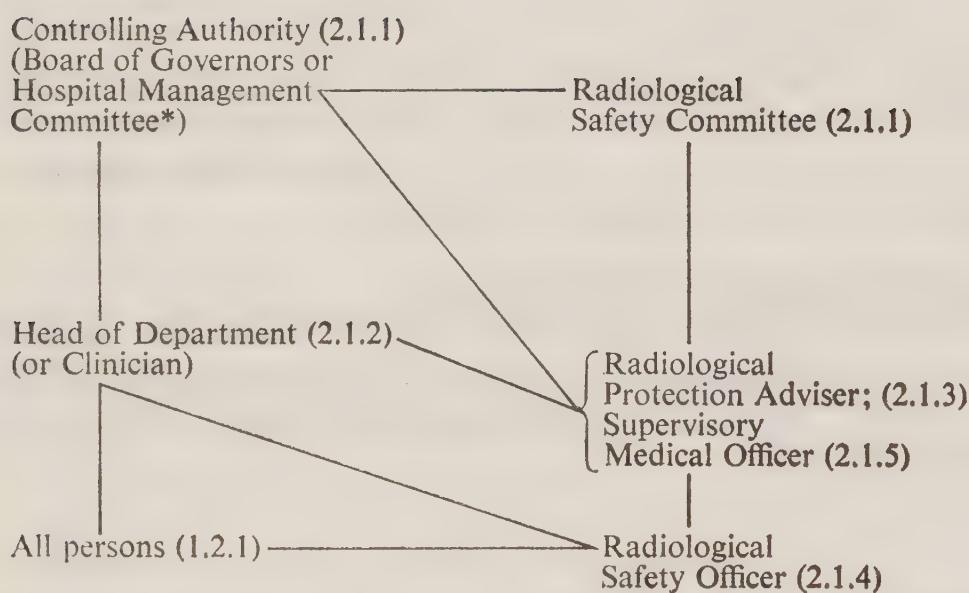
- iii By discharge to the foul water drainage system provided the activity does not exceed 100 microcuries of thorium-X in any week.

These conditions also apply to premises of medical practitioners and of pharmacists. The appropriate orders should be consulted for the precise conditions subject to which exemption is granted.

# APPENDIX A

## RESPONSIBILITY FOR RADIOLOGICAL SAFETY ARRANGEMENTS

The example below indicates the type of administrative organization suitable in large National Health Service hospitals. Some modification may be necessary in smaller hospitals.



\*In Scotland, Board of Management.

## APPENDIX B

# MAXIMUM PERMISSIBLE DOSES

Maximum permissible doses and dose limits.

### **General**

**1** The values of the maximum permissible doses and dose limits given in rems in Tables B1 and B2 are based on the recommendations of the International Commission on Radiological Protection<sup>23</sup> and take into account the views of the Medical Research Council.

### **Additivity of doses**

**2** For the levels of dose given in Table B1 the total dose in any organ or tissue due to occupational exposure comprises the dose received from external sources during working hours and the dose contributed by internal sources taken into the body during working hours. The total dose does not include any medical exposure which occupationally exposed persons may receive as patients or exposure to natural background radiation.

The total dose for individual members of the public, to which the dose limits given in Table B2 apply, is that received from all exposure to external and internal sources, excepting medical exposure and exposure to natural background radiation.

### **Doses for occupationally exposed persons**

**3** The values of the maximum permissible doses for the various body organs and tissues of occupationally exposed persons are given in Table B1, which should be read in conjunction with the notes which follow it.

**Table B1**  
**MAXIMUM PERMISSIBLE DOSES FOR OCCUPATIONALLY EXPOSED PERSONS**

Part of body	Annual dose	Quarterly dose	Planned special exposures	
			Single event	Lifetime
Gonads, red bone-marrow and whole body	5 rems*	3 rems (1.3 rems to the abdomens of women of reproductive capacity)	10 rems	25 rems
Bone, thyroid and skin of whole body	30 rems	15 rems	60 rems	150 rems
Hands, forearms, feet and ankles	75 rems	40 rems	150 rems	375 rems
Any single organ (excluding gonads, red bone-marrow, bone, thyroid and skin of whole body)	15 rems	8 rems	30 rems	75 rems

\*If the person was occupationally exposed before 18 years of age, subsequent exposure of the gonads, red bone-marrow and whole body should be controlled so that the dose accumulated up to 30 years of age does not exceed 60 rems.

### Notes on Table B1

- a** If there is reason to suppose that doses are being accumulated at grossly irregular rates, the quarterly maximum should be applied to a period of 13 consecutive weeks instead of a calendar quarter.
- b** The annual maximum permissible dose of 5 rems for the gonads, red bone-marrow, and whole body replaces the cumulative dose of  $5(N-18)$  rems where N is the person's age in years, formerly used by the ICRP and given in the previous edition of this Code. However, the quarterly maxima for the gonads, red bone-marrow and whole body may, in exceptional cases, be repeated in successive quarters, providing the total dose accumulated at no time exceeds  $5(N-18)$  rems, where N is the person's age in years. For this purpose it must be assumed, if information about the dose received by a person during any period of employment in which he was exposed to radiation is not available, that he received the currently recommended maximum permissible dose in each year of that period. It is emphasized that only exceptional circumstances can justify this relaxation of the annual maximum.
- c** Apart from the special limit of 1.3 rems in a calendar quarter which applies to the abdominal exposure of women of reproductive capacity, the dose of the foetus of a pregnant

woman who is occupationally exposed must not exceed 1 rem during the term of her pregnancy which remains after it has been diagnosed.

**d** Planned special exposures may be needed to meet situations which occur infrequently during normal operations. They must not be permitted if the sum of the anticipated dose and the worker's previously accumulated dose exceeds  $5(N-18)$  rems, where  $N$  is the worker's age in years. They must not be allowed for women of reproductive capacity. Planned special exposures must never be allowed unless alternative techniques, which do not involve such exposure of workers, are either unavailable or impracticable.

**e** It is unrealistic to specify dose limits for emergency exposures, whose justification will be the rescue of individuals, the prevention of the exposure of a large number of people, or the saving of a valuable installation. In these cases the acceptability of the dose will depend on the importance of the objective. Persons must be informed about the risks before they accept such exposures. It is also, of course, impossible to specify limits for accidental exposures. The action which must be taken when persons receive emergency exposures is described in sections 2.3.6 and 2.3.7 of this Code.

### Doses for patients

**4** The concepts of 'maximum permissible dose' and 'dose limit' are not applicable in the case of patients undergoing diagnostic examination or therapy with ionizing radiations. It is nevertheless desirable to limit the exposure of patients to the minimum value consistent with medical requirements. Special restrictions which apply to the radiological examination of women of reproductive capacity are given in Section 7 of the Code.

### 'Dose Limits' for members of the public

**5** The dose limits which apply to members of the public are given in Table B2.

Table B2  
DOSE LIMITS FOR MEMBERS OF THE PUBLIC

Part of body	Dose in 1 year (in rems)
Gonads, red bone-marrow and whole body	0.5
Bone, thyroid and skin of whole body	3 (1.5 rems to the thyroid of children up to 16 years of age)
Hands, forearms, feet and ankles	7.5
Any single organ (excluding gonads, red bone-marrow, bone, thyroid, and skin of whole body)	1.5

## Dose equivalent

6 The biological effectiveness of a given absorbed dose of one type of radiation is not necessarily the same as that of an equal absorbed dose of another type of radiation. The quantity obtained by multiplying the absorbed dose by certain factors designed to take account of differences in biological effectiveness is called the 'dose equivalent' (DE). The unit of DE is the 'rem'. The dose equivalent is calculated by multiplying the absorbed dose in rads by a quality factor (QF) to take account of differences in linear energy transfer (L<sub>oo</sub>) between different types of radiation, and, in certain cases, by other modifying factors to take account of, for example, non-uniform spatial distribution of absorbed dose. In this Code the term 'dose' is generally used in the sense of 'dose equivalent', for example, in the phrases 'maximum permissible dose' and 'dose limit'.

In Table B3 are given the values of QF for certain types of radiation.

**Table B3**  
VALUES OF QUALITY FACTOR USED IN DEFINING  
MAXIMUM PERMISSIBLE DOSE

Type of radiation	Quality factor
X-rays; $\gamma$ -rays; electrons; and $\beta$ -rays	1.0
Neutrons and protons* up to 10 MeV	10
Naturally occurring $\alpha$ -particles	10
Heavy recoil particles	20

\*If the energy of the neutron or proton is known, the particle flux density (in particles  $\text{cm}^{-2} \text{s}^{-1}$ ) corresponding to a dose of 1 mrem  $\text{h}^{-1}$  in tissue can be obtained direct from the curves given in Figure 3.4 (3) of the 'Handbook of Radiological Protection, Part 1: Data' <sup>45</sup>. Where the energy of the neutrons and protons is not known, simplifying procedures are justifiable, provided they do not result in an underestimate of dose equivalent. As an example of such a simplification, the ICRP Publication 9<sup>23</sup> suggests a single QF value of 10 for all fast neutrons. This is the value listed in Table B3. A similar single value for fast protons was suggested by the ICRP in 1955.

## APPENDIX C

# MAXIMUM PERMISSIBLE BODY BURDENS AND MAXIMUM PERMISSIBLE CONCENTRATIONS IN AIR AND WATER FOR RADIONUCLIDES WHICH ARE IN MEDICAL AND DENTAL USE

1 Recommendations have been made by the ICRP for the maximum permissible body burdens and the maximum permissible concentrations in air and water for many of the radionuclides at present in medical and dental use. The recommended values are for occupationally exposed persons and the maximum permissible concentrations have been calculated on the basis of continuous exposure for 40 hours a week during 50 weeks a year. Under such conditions of exposure, the annual doses received by the organs of the body will reach but will never exceed those given in column 2 of Table B1. The following table includes all the radionuclides at present in medical and dental use, and lists those organs for which the values of the maximum permissible concentrations for soluble and insoluble compounds are lowest. For those radionuclides for which no ICRP values are available, assessments have been made using the ICRP concepts (see ICRP Publication 2<sup>16</sup> and 6<sup>20</sup>). These tables give the maximum permissible intakes for these radionuclides when they are incorporated in simple compounds or in ionic form. When these radionuclides are used to label pharmaceuticals then the metabolism of the radiopharmaceutical will determine the fate of the radionuclide and this may lead to quite different critical organs and maximum permissible levels (see ICRP Publication 17<sup>30</sup>).

2 It is possible to use the concentrations given in the table to calculate the corresponding maximum permissible annual intakes by inhalation or by ingestion, the factors by which to multiply the concentrations being  $2.5 \times 10^9$  and  $2.7 \times 10^5$  respectively. These factors are respectively the air and water intakes measured in  $\text{cm}^3$  for 'the standard man' (see ICRP Publication 2<sup>16</sup> and 6<sup>20</sup>) working 40 hours per week for 50 weeks in a year. The maximum intake of a radionuclide in any one quarter is limited according to the ICRP (see ICRP Publication 9<sup>23</sup>) to an amount corresponding to one-half of the maximum permissible annual intake.

3 Irrespective of the rate at which they enter the body, intakes of radionuclides which are equal to these maximum permissible annual intakes will result in dose commitments (the dose delivered in 50 years from the date of intake) to the organs concerned which are equal to the appropriate annual limits on dose shown in column 2 of Table B1. As indicated in Sections 1.2.1.i.a & b, workers must be designated if there is a likelihood that their annual intakes and hence doses will exceed three-tenths the maximum permissible annual intakes calculated as described above, consideration being given to all modes of entry. If the worker is also exposed to external radiation, the levels of intake of radionuclides must be reduced to such an extent that the values for the maximum permissible doses are not exceeded. Similarly, if the worker is exposed to more than one radionuclide, the doses from each radionuclide must be aggregated to obtain the total dose received by the various organs of the body and again the maximum permissible doses must not be exceeded. As the table includes values only for those organs for which the maximum permissible concentrations are lowest, it will sometimes be necessary to obtain additional values in order that the summation can be undertaken. These values may be already listed by the ICRP: alternatively, they may be obtained from the National Radiological Protection Board or be calculated according to the ICRP concepts.

4 In accordance with ICRP Publication 9<sup>23</sup>, all values of maximum permissible annual doses given in column 2 of Table B1 must be reduced by a factor 10 for members of the public, with the exception that for children up to 16 years of age the annual dose to thyroid should be reduced by a factor 20, i.e. to 1.5 rem. The values of maximum permissible concentrations given in the table and the values of the corresponding maximum permissible intakes calculated as described above apply only for occupationally exposed persons. These values should, therefore, be reduced by a factor 10 for individual adult members of the public. The values are not generally applicable to children because they differ from adults in respect of organ masses, uptake and retention of radionuclides, and air and water intakes. If children are involved, it is therefore necessary to give consideration to all these factors and no general guidance is at present available. Advice on specific problems can, however, be obtained from the National Radiological Protection Board.

Table C1

MAXIMUM PERMISSIBLE BODY BURDENS AND MAXIMUM PERMISSIBLE CONCENTRATIONS IN AIR AND WATER APPLICABLE TO ADULTS IN THE COURSE OF THEIR WORK (40 HOUR WEEK)

Radionuclide	Critical Organ	Maximum permissible body burden (in $\mu\text{Ci}$ )	Maximum permissible concentrations (in $\mu\text{Ci cm}^{-3}$ )	
			In air	In water
Hydrogen-3 As tritiated water	Body tissue	$10^3$	$5 \times 10^{-6}$	0.1
*Carbon-11	Fat	15	$2 \times 10^{-4}$	1
	Total Body	18	$2 \times 10^{-4}$	1
	Lung	—	$7 \times 10^{-5}$	—
Carbon-14 as Carbon dioxide (sol) (submersion)	Fat Total Body	300 —	$4 \times 10^{-6}$ $5 \times 10^{-5}$	0.02 —
*Nitrogen-13	Total Body	16	$3 \times 10^{-4}$	2
	Lung	—	$10^{-4}$	—
*Oxygen-15	Total Body	14	$10^{-3}$	9
	Lung	—	$9 \times 10^{-3}$	—
Fluorine-18	G.I.(SI)	—	$5 \times 10^{-6}$	0.02
	G.I.(LLI)	—	$3 \times 10^{-6}$	0.01
Sodium-22	Total Body	10	$2 \times 10^{-7}$	$10^{-3}$
	Lung G.I.(LLI)	—	$9 \times 10^{-9}$	—
		—	—	$9 \times 10^{-4}$
Sodium-24	G.I.(SI)	—	$10^{-6}$	$6 \times 10^{-3}$
	G.I.(LLI)	—	$10^{-7}$	$8 \times 10^{-4}$
Phosphorus-32	Bone	6	$7 \times 10^{-8}$	$5 \times 10^{-4}$
	Lung G.I.(LLI)	—	$8 \times 10^{-8}$	—
		—	—	$7 \times 10^{-4}$
Sulphur-35	Testis	90	$3 \times 10^{-7}$	$2 \times 10^{-3}$
	Lung G.I.(LLI)	—	$3 \times 10^{-7}$	—
		—	—	$8 \times 10^{-3}$
Chlorine-36	Total Body	80	$4 \times 10^{-7}$	$2 \times 10^{-3}$
	Lung (G.I.(LLI))	—	$2 \times 10^{-8}$	—
		—	—	$2 \times 10^{-3}$
Chlorine-38	G.I.(S)	—	$3 \times 10^{-6}$	0.01
	G.I.(S)	—	$2 \times 10^{-6}$	0.01
Potassium-42	G.I.(S)	—	$2 \times 10^{-6}$	$9 \times 10^{-3}$
	G.I.(LLI)	—	$10^{-7}$	$6 \times 10^{-4}$
*Potassium-43	Total Body	20	—	$2 \times 10^{-2}$
	G.I.(LLI)	—	$3 \times 10^{-7}$	—
	G.I.(LLI)	—	$2 \times 10^{-7}$	$2 \times 10^{-3}$

\*Assessed by the National Radiological Protection Board.

Radionuclide	Critical Organ	Maximum permissible body burden (in $\mu\text{Ci}$ )	Maximum permissible concentrations (in $\mu\text{Ci cm}^{-3}$ )	
			In air	In water
Calcium-45 (sol) (insol)	Bone Lung G.I.(LLI)	30 — —	$3 \times 10^{-8}$ $10^{-7}$ —	$3 \times 10^{-4}$ — $5 \times 10^{-3}$
Calcium-47 (sol) (insol)	Bone Lung G.I.(LLI)	5 — —	$2 \times 10^{-7}$ $2 \times 10^{-7}$ $2 \times 10^{-7}$	$10^{-3}$ — $10^{-3}$
Scandium-47 (sol) (insol)	G.I.(LLI) G.I.(LLI)	— —	$6 \times 10^{-7}$ $5 \times 10^{-7}$	$3 \times 10^{-3}$ $3 \times 10^{-3}$
Chromium-51 (sol) (insol)	Total Body G.I.(LLI) Lung G.I.(LLI)	800 — — —	$10^{-5}$ $10^{-5}$ $2 \times 10^{-6}$ —	— 0.05 — 0.05
*Iron-52 (sol) (insol)	Total Body G.I.(LLI)	4 —	$4 \times 10^{-6}$ $4 \times 10^{-7}$	0.1 $4 \times 10^{-3}$
Iron-55 (sol) (insol)	Spleen Lung G.I.(LLI)	$10^3$ — —	$9 \times 10^{-7}$ $10^{-6}$ —	0.02 — 0.07
Iron-59 (sol) (insol)	Spleen G.I.(LLI) Lung G.I.(LLI)	20 — — —	$10^{-7}$ — $5 \times 10^{-8}$ —	— $2 \times 10^{-3}$ — $2 \times 10^{-3}$
*Cobalt-56 (sol) (insol)	G.I.(LLI) Lung G.I.(LLI)	— — —	$2 \times 10^{-7}$ $10^{-8}$ —	$10^{-3}$ — $8 \times 10^{-4}$
Cobalt-57 (sol) (insol)	G.I.(LLI) Lung G.I.(LLI)	— — —	$3 \times 10^{-6}$ $2 \times 10^{-7}$ —	0.02 — 0.01
Cobalt-58 (sol) (insol)	G.I.(LLI) Lung G.I.(LLI)	— — —	$8 \times 10^{-7}$ $5 \times 10^{-8}$ —	$4 \times 10^{-3}$ — $3 \times 10^{-3}$
Cobalt-60 (sol) (insol)	G.I.(LLI) Lung G.I.(LLI)	— — —	$3 \times 10^{-7}$ $9 \times 10^{-9}$ —	$10^{-3}$ — $10^{-3}$
Copper-64 (sol) (insol)	G.I.(LLI)	— —	$2 \times 10^{-6}$ $10^{-6}$	0.01 $6 \times 10^{-3}$
Zinc-65 (sol) (insol)	Total Body Prostate Liver Lung G.I.(LLI)	60 70 80 — —	$10^{-7}$ $10^{-7}$ $10^{-7}$ $6 \times 10^{-8}$ —	$3 \times 10^{-3}$ — — — $5 \times 10^{-3}$

\*Assessed by the National Radiological Protection Board.

Radionuclide	Critical Organ	Maximum permissible body burden (in $\mu\text{Ci}$ )	Maximum permissible concentrations (in $\mu\text{Ci cm}^{-3}$ )	
			In air	In water
*Gallium-67 (sol) (insol)	{ G.I.(LLI)	— —	$2 \times 10^{-6}$ $2 \times 10^{-6}$	$9 \times 10^{-3}$ $9 \times 10^{-3}$
*Gallium-68 (sol) (insol)	Liver G.I.(S)	6 —	$4 \times 10^{-5}$ $3 \times 10^{-6}$	100 $2 \times 10^{-2}$
*Germanium-68 (sol) (insol)	Kidney Lung G.I.(LLI)	0.7 — —	$3 \times 10^{-7}$ $7 \times 10^{-9}$ —	$7 \times 10^{-2}$ — $4 \times 10^{-2}$
Arsenic-74 (sol) (insol)	G.I.(LLI) Lung G.I.(LLI)	— — —	$3 \times 10^{-7}$ $10^{-7}$ —	$2 \times 10^{-3}$ — $2 \times 10^{-3}$
Arsenic-76 (sol) (insol)	G.I.(LLI)	— —	$10^{-7}$ $10^{-7}$	$6 \times 10^{-4}$ $6 \times 10^{-4}$
Selenium-75 (sol) (insol)	Kidney Total Body Lung G.I.(LLI)	90 100 — —	$10^{-6}$ $10^{-6}$ $10^{-7}$ —	$9 \times 10^{-3}$ — — $8 \times 10^{-3}$
Bromine-82 (sol) (insol)	Total Body G.I.(SI) G.I.(LLI)	10 — —	$10^{-6}$ — $2 \times 10^{-7}$	$8 \times 10^{-3}$ $8 \times 10^{-3}$ $10^{-3}$
Krypton-85 (submersion)	Total Body	—	$10^{-5}$	—
*Rubidium-81 (sol) (insol)	Total Body G.I.(ULI) G.I.(ULI)	4 — —	$3 \times 10^{-6}$ $3 \times 10^{-6}$ $3 \times 10^{-6}$	$2 \times 10^{-2}$ — $10^{-2}$
Rubidium-86 (sol) (insol)	Total Body Pancreas Lung G.I.(LLI)	30 30 — —	$3 \times 10^{-7}$ $3 \times 10^{-7}$ $7 \times 10^{-8}$ —	$2 \times 10^{-3}$ $2 \times 10^{-3}$ — $7 \times 10^{-4}$
Strontium-85 (sol) (insol)	Total Body Lung G.I.(LLI)	60 — —	$2 \times 10^{-7}$ $10^{-7}$ —	$3 \times 10^{-3}$ — $5 \times 10^{-3}$
*Strontium-87m (sol) (insol)	G.I.(ULI) G.I.(ULI)	— —	$3 \times 10^{-5}$ $3 \times 10^{-5}$	0.2 0.2
Strontium-90 (sol) (insol)	Bone Lung G.I.(LLI)	2 — —	$10^{-9}$ $5 \times 10^{-9}$ —	$10^{-5}$ — $10^{-3}$
*Yttrium-87 (sol) (insol)	G.I.(LLI) G.I.(LLI)	— —	$8 \times 10^{-7}$ $6 \times 10^{-7}$	$4 \times 10^{-3}$ $4 \times 10^{-3}$
Yttrium-90 (sol) (insol)	G.I.(LLI)	— —	$10^{-7}$ $10^{-7}$	$6 \times 10^{-4}$ $6 \times 10^{-4}$

\*Assessed by the National Radiological Protection Board.

Radionuclide	Critical Organ	Maximum permissible body burden (in $\mu\text{Ci}$ )	Maximum permissible concentrations (in $\mu\text{Ci cm}^{-3}$ )	
			In air	In water
Molybdenum-99 (sol) (insol)	Kidney G.I.(LLI)	8 —	$7 \times 10^{-7}$ $2 \times 10^{-7}$	$5 \times 10^{-3}$ $10^{-3}$
Technetium-99m (sol) (insol)	G.I.(ULI) G.I.(ULI)	— —	$4 \times 10^{-5}$ $10^{-5}$	0.2 0.08
Indium-113m (sol) (insol)	G.I.(ULI) G.I.(ULI)	— —	$8 \times 10^{-6}$ $7 \times 10^{-6}$	0.04 0.04
Tin-113 (sol) (insol)	Bone G.I.(LLI) Lung G.I.(LLI)	30 — — —	$4 \times 10^{-7}$ — $5 \times 10^{-8}$ —	— $2 \times 10^{-3}$ — $2 \times 10^{-3}$
Tellurium-132 (sol) (insol)	G.I.(LLI)	— —	$2 \times 10^{-7}$ $10^{-7}$	$9 \times 10^{-4}$ $6 \times 10^{-4}$
*Iodine-123 (sol) (insol)	Thyroid G.I.(LLI)	5 —	$8 \times 10^{-7}$ $6 \times 10^{-6}$	$6 \times 10^{-3}$ $3 \times 10^{-2}$
*Iodine-125 (sol) (insol)	Thyroid Lung G.I.(LLI)	10 — —	$2 \times 10^{-8}$ $5 \times 10^{-7}$ —	$10^{-4}$ — $2 \times 10^{-2}$
Iodine-131 (sol) (insol)	Thyroid Lung G.I.(LLI)	0.7 — —	$9 \times 10^{-9}$ $3 \times 10^{-7}$ $3 \times 10^{-7}$	$6 \times 10^{-5}$ — $2 \times 10^{-3}$
Iodine-132 (sol) (insol)	Thyroid G.I.(ULI)	0.3 —	$2 \times 10^{-7}$ $9 \times 10^{-7}$	$2 \times 10^{-3}$ $5 \times 10^{-3}$
Xenon-133 (submersion)	Total Body	—	$10^{-5}$	—
*Caesium-129 (sol) (insol)	Total Body G.I.(LLI)	11 —	$10^{-6}$ $3 \times 10^{-6}$	$8 \times 10^{-3}$ $2 \times 10^{-2}$
Caesium-131 (sol) (insol)	Total Body Liver Lung G.I.(LLI)	700 800 — —	$10^{-5}$ $10^{-5}$ $3 \times 10^{-6}$ —	0.07 — — 0.03
Caesium-137 (sol) (insol)	Total Body Lung G.I.(LLI)	30 — —	$6 \times 10^{-8}$ $10^{-8}$ —	$4 \times 10^{-4}$ — $10^{-3}$
Promethium-147 (sol) (insol)	Bone G.I.(LLI) Lung G.I.(LLI)	60 — — —	$6 \times 10^{-8}$ — $10^{-7}$ —	— $6 \times 10^{-3}$ — $6 \times 10^{-3}$
Thulium-170 (sol) (insol)	Bone G.I.(LLI) Lung G.I.(LLI)	9 — — —	$4 \times 10^{-8}$ — $3 \times 10^{-8}$ —	— $10^{-3}$ — $10^{-3}$

\*Assessed by the National Radiological Protection Board.

Radionuclide	Critical Organ	Maximum permissible body burden (in $\mu\text{Ci}$ )	Maximum permissible concentrations (in $\mu\text{Ci cm}^{-3}$ )	
			In air	In water
Tantalum-182	(sol)	7	$4 \times 10^{-8}$	$10^{-3}$
	(insol)	$\begin{cases} \text{Liver} \\ \text{G.I.(LLI)} \end{cases}$	—	$10^{-3}$
Iridium-192	(sol)	6	$10^{-7}$	$10^{-3}$
	(insol)	$\begin{cases} \text{Kidney} \\ \text{G.I.(LLI)} \end{cases}$	—	$10^{-3}$
Gold-198	(sol)	—	$3 \times 10^{-7}$	$2 \times 10^{-3}$
	(insol)	$\begin{cases} \text{G.I.(LLI)} \end{cases}$	$2 \times 10^{-7}$	$10^{-3}$
Mercury-197	(sol)	Kidney	$10^{-6}$	$9 \times 10^{-3}$
	(insol)	G.I.(LLI)	$3 \times 10^{-6}$	0.01
Mercury-203	(sol)	Kidney	$7 \times 10^{-8}$	$5 \times 10^{-4}$
	(insol)	$\begin{cases} \text{Lung} \\ \text{G.I.(LLI)} \end{cases}$	$10^{-7}$ —	$3 \times 10^{-3}$
Thallium-204	(sol)	10	$6 \times 10^{-7}$	$3 \times 10^{-3}$
	(insol)	$\begin{cases} \text{G.I.(LLI)} \\ \text{Lung} \\ \text{G.I.(LLI)} \end{cases}$	— $3 \times 10^{-8}$ —	$2 \times 10^{-3}$
Lead-210	(sol)	0.4	$10^{-10}$	$4 \times 10^{-6}$
	(insol)	$\begin{cases} \text{Total Body} \\ \text{Lung} \\ \text{G.I.(LLI)} \end{cases}$	$4 \times 10^{-6}$ $2 \times 10^{-10}$ —	$5 \times 10^{-3}$
Bismuth-206	(sol)	1	$2 \times 10^{-7}$	$10^{-3}$
	(insol)	$\begin{cases} \text{G.I.(LLI)} \\ \text{Lung} \\ \text{G.I.(LLI)} \end{cases}$	$2 \times 10^{-7}$ $10^{-7}$ —	$10^{-3}$
Radon-220	Lung	—	$3 \times 10^{-7}$	—
Radon-222	Lung	—	$3 \times 10^{-8}$	—
Radium-224 (Thorium-X)	(sol)	Bone	$5 \times 10^{-9}$	$7 \times 10^{-5}$
	(insol)	$\begin{cases} \text{Lung} \\ \text{G.I.(LLI)} \end{cases}$	$7 \times 10^{-10}$ —	$2 \times 10^{-4}$
Radium-226	(sol)	0.06	$3 \times 10^{-11}$	$4 \times 10^{-7}$
	(insol)	$\begin{cases} \text{G.I.(LLI)} \end{cases}$	$2 \times 10^{-7}$	$9 \times 10^{-4}$
Californium-252	(sol)	0.01	$6 \times 10^{-12}$	—
	(insol)	$\begin{cases} \text{Bone} \\ \text{G.I.(LLI)} \end{cases}$	— $3 \times 10^{-11}$	$2 \times 10^{-4}$
		$\begin{cases} \text{Lung} \\ \text{G.I.(LLI)} \end{cases}$	— —	$2 \times 10^{-4}$

## APPENDIX D

# DERIVED WORKING LIMITS FOR SURFACE CONTAMINATION

**1** The derived working limits for surface contamination (other than contamination which cannot be removed by normal cleaning methods) are given in Table D1 and decontamination procedures must be instituted when these levels are exceeded.

**Table D1**

Category	Surface	Derived Working Limit (Microcurie per square centimetre)		
<b>A</b>	Surfaces of the interiors and contents of glove boxes and fume cupboards.	The minimum that is reasonably practicable		
<b>B</b>	Surfaces of active areas and of plant, apparatus, equipment (including personal protective equipment), materials and articles within active areas, other than those of category A.	Alpha emitting radionuclides	*All other radio-nuclides except tritium	$10^{-3}$
		In Class 1 of Appendix L	In Classes 2 to 4 of Appendix L	
		$10^{-4}$	$10^{-3}$	
<b>C</b>	Surfaces of the body.	$10^{-5}$	$10^{-5}$	$10^{-4}$
<b>D</b>	All other surfaces, e.g. inactive areas, personal clothing, hospital bedding.	$10^{-5}$	$10^{-4}$	$10^{-4}$

\*These figures are not applicable to tritium. It is difficult to measure tritium contamination on surfaces and where considered necessary control should be by urine analysis. Advice on details of the methods that should be used may be obtained on application from the National Radiological Protection Board.

**2** In the case of contamination that can be rubbed off surfaces (other than those of the body and of fabrics and the like), it must be assumed, in the absence of evidence to the contrary, that one-tenth of the removable contamination has been transferred from the area that has been rubbed.

**3** The contamination of surfaces of the body and of fabrics and the like must be assessed by means of direct measurement, the results of which must be considered in accordance with the values given in Table D1 and the recommendations of the Code, for example those of Sections 6.8 and 6.9.

**4** Contamination on surfaces other than those of the body, so fixed that it cannot be removed by normal cleaning methods, must either be at such a level that no person can receive radiation doses in excess of the values given in Tables B1 and B2 as appropriate, or shielding must be provided in order to achieve this result.

**5** The results of measurements of contamination of surfaces of the body shall be averaged over an area not exceeding  $100\text{ cm}^2$ , except in the case of the hands for which the whole area of a hand (nominally  $300\text{ cm}^2$ ) may be used. For other surfaces, the results of measurements of removable contamination may be averaged over an area not exceeding  $1000\text{ cm}^2$  in the case of floors, walls and ceilings and over an area not exceeding  $300\text{ cm}^2$  in all other cases.

**6** A uniform surface contamination of  $10^{-4}\mu\text{Ci cm}^{-2}$  of a beta-emitting radionuclide delivers a dose-rate of about  $1\text{ mrad h}^{-1}$  to the basal layer of the epidermis when the contamination is in contact with the skin. The dose-rate decreases with decreasing maximum energy of the beta particles and with increasing depth of tissue.

**7** The derived working limits given in Table D1 are similar in magnitude to the maximum permissible levels given in the Code of Practice for the Protection of Persons Exposed to Ionising Radiations in Research and Teaching<sup>46</sup> and in the Ionising Radiations (Unsealed Radioactive Substances) Regulations 1968<sup>4</sup>.

**APPENDIX E**  
**TRANSFER RECORD FOR**  
**DESIGNATED PERSONS**

**1 Full names of worker.**

**2 Sex.**

**3 Private address of worker.**

**4 Date of birth of worker.**

**5 National Insurance number.**

**6 Name of employer.**

**7 Address of place of employment.**

(6 and 7 refer to the employment which the worker is about to leave).

**8 Periods during which:**

(a) The worker was in employment as designated person or former equivalent status		(b) External radiation doses were recorded	
From	To	From	To

Includes work as a designated person or former equivalent status prior to the work the person concerned is leaving.

**9 External dose record (whole body):**

	X, $\gamma$ and $\beta$ (rads in air)	X and $\gamma$ (rads in air)	neutrons (rems)
Cumulative total dose from commencement of first employment as designated person up to the end of the last completed calendar quarter			
Dose received during the current calendar quarter			

State dose units used if they are not 'rads in air'. Also indicate what allowance has been made for periods when employed as a designated person, or former equivalent status, but not subjected to dose measurements.

**10 External dose record (for parts of body other than the trunk).**

If the designated person has any record (additional to that given in Section 9) of doses received by hands, forearms, feet and ankles, state these doses in the same way as in section 9.

**11 Further information:**

- i Any record of doses estimated from past or present deposition in the body of radioactive substances.
- ii Any occurrence of exposure in excess of the values of maximum permissible doses given in Appendix B of the Code of Practice for the Protection of Persons against Ionizing Radiations arising from Medical and Dental Use.

Date .....

Signed .....

(on behalf of

Employing Authority) .....

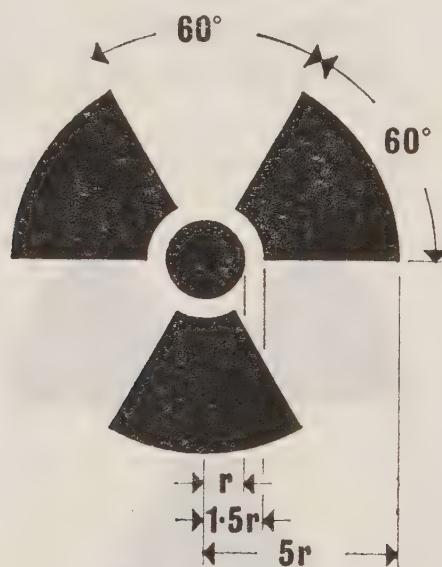
## APPENDIX F

# SYMBOL TO INDICATE IONIZING RADIATIONS

1 There is a British Standard specification (British Standard 3510:1968<sup>43</sup>) for symbols to denote the actual or potential presence of ionizing radiations and to identify objects, devices, materials or substances which emit ionizing radiations. The Standard does not specify any radiation levels at which symbols are to be used.

### Shape and proportions

2 The basic symbol is of the following design:



### Colours

3 The areas above shown shaded are black. The symbol should be placed on a yellow background, of a colour approximating to colour No. 309 of British Standard 381C<sup>41</sup>, or reference 0-001 of British Standard 2660<sup>38</sup> of sufficient area for it to be distinctive. (In certain applications outside the medical and dental field, e.g. transport, the symbol may appear on a white background.)

### Application to medical and dental use

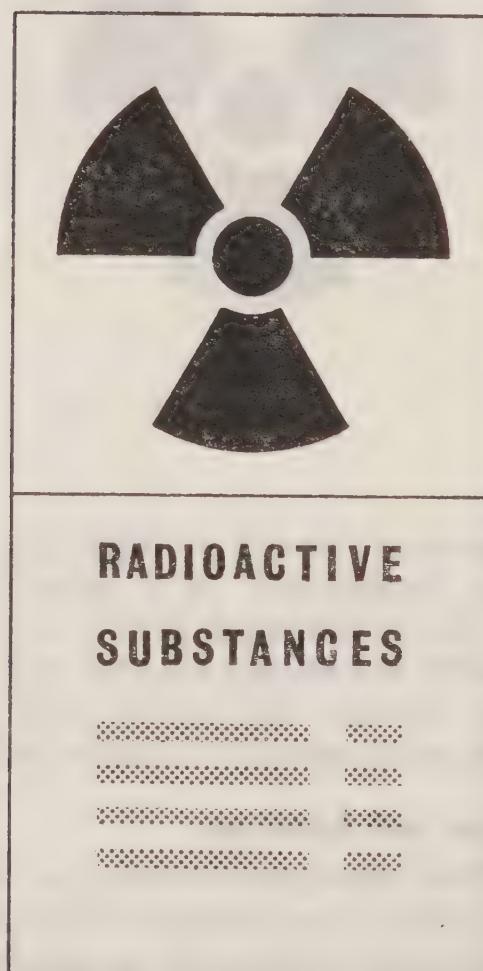
4 The standard allows appropriate wording or other symbols to be used in association with the basic symbol, but for medical and dental use it is recommended that words only should be added. Wording might be used to indicate the nature of the source of radiation, the type of radiation, the limits of time which may be spent in the proximity, etc.

## General

5 The basic symbol must be used only to signify the actual or potential presence of ionizing radiations. It must be as prominent as is practical, and of a size consistent with the size of the equipment or material to which it is affixed providing that the proportions shown above are maintained. The symbol must be recognizable from a safe distance. Any wording added to the symbol must not detract from its clarity, e.g. by being larger or more brightly coloured. No lettering should be superimposed on the symbol, and any wording used must be kept to the minimum necessary.

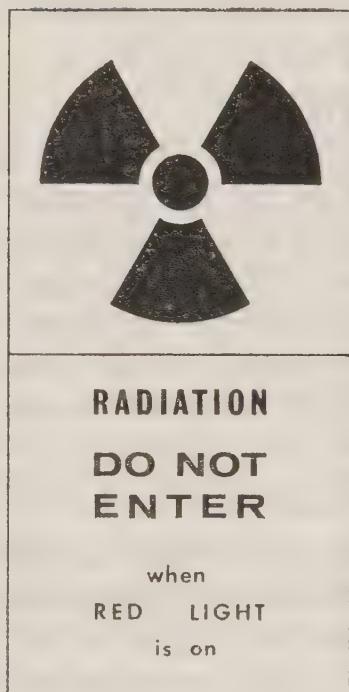
The following are some applications of the symbol:

Example 1. Sign  
on a storage  
cabinet for radio-  
active substances



Appropriate words may be added as indicated.

Example 2. Sign on a door giving access to a room in which radiation sources or X-rays are used



Example 3. Label on a bottle containing radioactive solution



Appropriate words may be added as indicated.

## APPENDIX G

# TUBE AND SOURCE HOUSINGS

**1** In assessing compliance with the requirements for tube and source housings, or storage containers it is adequate for measurements to be averaged over an area up to but not exceeding  $100 \text{ cm}^2$  at a focal or source distance of 1 metre and  $10 \text{ cm}^2$  at a distance of 5 cm from the surface of the housing.

### Diagnostic-type tube housing (see Section 3.10.1)

**2** The protective housing of a diagnostic X-ray tube should be so constructed that, at every rating specified by the manufacturer for the tube in that housing, the leakage radiation at a focal distance of 1 metre does not exceed 100 mR in one hour. (X-ray tubes are now available whose housings limit the leakage radiation to not more than 10 mR in one hour at a focal distance of 1 metre. As old tubes are replaced, tubes whose housings are of this standard should be installed.)

### Therapeutic-type tube housing (see Section 4.2.1)

**3** The protective housing of a therapeutic X-ray tube capable of operating at voltages up to 500 kV should be so constructed that, at every rating specified by the manufacturer for the tube in that housing, the exposure rate from the leakage radiation measured at a focal distance of 1 metre does not exceed  $1 \text{ R h}^{-1}$ , nor  $30 \text{ R h}^{-1}$  at any position accessible to the patient at a distance of 5 cm from the surface of the housing or its accessory equipment.

**4** The protective housing of a therapeutic X-ray tube capable of operating at voltages above 500 kV must be so constructed that, at every rating specified by the manufacturer for the tube in that housing, the exposure rate from the leakage radiation measured at a focal distance of 1 metre does not exceed 0.1% of the exposure rate of the useful beam at that distance.

### High tension generators and other auxiliary equipment

**5** In cases where radiation may be produced by high tension generators and other auxiliary equipment (e.g. from rectifying valves), adequate protection must be provided for all persons.

### Teletherapy-type source housing (see Section 4.4.1)

**6** Radioactive sources used for teletherapy should be enclosed in housings which satisfy the following requirements:

i Beam-control mechanism in 'OFF' position:

a At a source distance of 1 metre the exposure rate from the leakage radiation does not exceed  $2 \text{ mR h}^{-1}$ .

b At 5 cm from the housing surface in any readily accessible position, the exposure rate from the leakage radiation does not exceed  $20 \text{ mR h}^{-1}$  unless the useful beam exposure rate at a source distance of 1 metre is less than  $100 \text{ R h}^{-1}$ , in which case the corresponding exposure rate of the leakage radiation does not exceed  $40 \text{ mR h}^{-1}$ \*.

ii Beam control mechanism in 'ON' position:

- a When the useful beam exposure rate at a source distance of 1 metre is not less than  $100 \text{ R h}^{-1}$  the exposure rate from the leakage radiation at a similar distance does not exceed either  $1 \text{ R h}^{-1}$  or 0.1 per cent of the useful beam whichever is the greater.
- b When the useful beam exposure rate is less than  $100 \text{ R h}^{-1}$  at a source distance of 1 metre, the exposure rate from the leakage radiation at that distance does not exceed 1 per cent of the useful beam.

**Remotely operated after-loading equipment using individual sources totalling 0.5 g radium equivalent or more (see Section 4.5.4).**

**7** When all the sources are within the storage container, the average exposure rate of the leakage radiation must not exceed  $2 \text{ mR h}^{-1}$  at any place readily accessible to the staff preparing a patient for treatment.

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\* The higher value of leakage radiation for equipment having a lower useful beam exposure rate is because such equipment is largely confined to head and neck units which for geometrical considerations cannot be provided with a higher degree of shielding.

## APPENDIX H

(Note. The following recommendations of the Radiotherapy Apparatus Safety Measures Panel for Safety Measures in the design of Linear Accelerators have been accepted by the Department of Health and Social Security. Report No. RASMP/68/2 Final; Ref. H/R1/19. This Report sets out guidelines for machines producing both electrons and X-rays; for machines producing only X-rays the Health Departments should be consulted.)

# REPORT OF THE RADIOTHERAPY APPARATUS SAFETY MEASURES PANEL ON REQUIREMENTS FOR DOSE CONTROL OF HIGH ENERGY X-RAYS AND ELECTRONS

(Applicable to equipment generating beams of energy greater than 2 MeV and dose-rates greater than 100 rads in air per minute at the treating distance)

### Equipment and Housing

1 There must be two dose integrating systems reading dose beyond the scattering foils (or beam flattening filter in the case of X-ray equipment) and as close to the patient as possible. These must, as far as possible, be kept electrically and mechanically separate, and arranged so that a failure in one system will not affect the other and accidental intercommunication between the two systems cannot occur. If it is necessary for any components, wiring or power supplies to be common to both integrating systems, these must be continuously monitored and interlocked with the accelerator so that a failure, partial or complete, will terminate the exposure. In any case, circuits must be arranged so that failure of the mains power supply to either system will terminate the exposure. One of the dosimeter channels must be capable of an absolute accuracy of  $\pm 2\%$  and should be used as the primary channel.

2 i The output displays from the two integrating dosimeters should be identical and placed close together on the control panel. The displays should be easy to read and must maintain their readings until driven back to zero, mechanically or electrically. Dual scale meters or push buttons to divide the scales by some factor must not be used. The indicating

device must read dose upwards to a set value so that any overdose will give a reading.

- ii Each integrating dosimeter circuit must independently be capable of switching the beam off when the pre-set dose is reached. Care must be taken to keep the two relay holding circuits physically separated. Both dosimeter tripping circuits should be capable of being tested independently, e.g. by interlocking against switch-on until the trip switch has been tested.
- iii The two dose systems should be designed in such a way that the secondary channel cuts off the beam at a dose not more than 40 rads higher than the pre-set dose on the primary channel regardless of the dose pre-set on the second channel. If possible this should be achieved by a single setting procedure.

**3** An automatic timer must be installed which can be set to switch off the beam when a pre-set time has elapsed. The timer should preferably be an electric count up timer which switches on and off with the beam and also retains its reading after switching off. Any detectable failure of the timer should cause the beam to switch off.

**4** An independent dose rate indicator must be provided. The display should be less prominent than that of the integrating dosimeters. In addition to a visual indication of dose rate an audible indication of rate should be provided either from the dose rate meter or the integrating dosimeters. The rate meter circuit must provide a high dose rate trip out for the beam, set to trip when the dose rate exceeds twice the maximum rate which the machine normally delivers for treatment purposes.

**5** There must be clear indications of treatment conditions and pre-set dose so that radiographers and radiotherapists can see at a glance that the settings are broadly correct (provided the meter indications are set accurately by the physicist).

**6** For conventional electron beam treatments the dose rate of the equipment should be so limited that the shortest treatment time normally used is about 20 seconds. (Times of less than 10 seconds are too short for manual switching off in an emergency).

**7** Wherever possible interlocks should be arranged so that they can be proved to have functioned each time they operate. Facilities must be provided so that interlocks that do not normally operate may be regularly checked by the users.

**8** Circuits must be provided so that the modality of treatment and the positioning of all optional devices such as wedge filters, carbon decelerators, scattering foils etc., are checked by the operation of a confirming switch or switches before each exposure can commence. No visual indication of the treatment conditions should be displayed until the correct confirming button has been pressed.

### **Operating Procedures**

**9** If any change takes place in the operating conditions involving the electron or X-ray output of a machine a dummy run must be made to test that the output and interlocks are correct.

**10** One integrating dosimeter must be set up and calibrated for the normal measurement of treatment dose; the second should act as a check on the primary dosimeter and should be set to trip the circuits at not more than 40 rads higher than the dose prescribed. (Reference 2.iii.)

**11** Radiographers should be trained to switch off if the integrating dosimeter readings differ by more than some agreed number of divisions. A routine procedure should be established which will enable them to check that all interlocks are functioning.

**12** Attention should be given to methods of recording various conditions of treatment. A permanent record should be kept of the dose given and the treatment time.

**13** The special problem of linear accelerator electron treatment is that there may be two or more combinations of scatterer and distance. This gives a multiplicity of calibration factors for attention during operation which does not occur in the X-ray operation of accelerators. The number of these dosimeter conversion factors or modalities should be kept to a minimum.

**14** Mental arithmetic under stressed conditions must be reduced to thinking in terms of one or two divisions on a meter as deviations from a norm, rather than by dividing or multiplying by some calibration factor. Dosemeter conversion tables for each modality must be permanently displayed.

## APPENDIX I

# PATIENTS LEAVING A HOSPITAL AFTER ADMINISTRATION OF RADIOACTIVE SUBSTANCES

### Introduction

**1** Details are given below of the basis of the recommendations of Section 8 of the Code and further guidance is given regarding the conditions under which patients being treated with radioactive substances may leave hospital and return to their homes. Information on post-mortem examinations, embalming and cremation is given in Appendix J.

### Protection Criteria

**2** The recommendations are based principally on considerations of external radiation from the patient in relation to the dose limits for individual members of the public and the possibility of damage to undeveloped photographic materials. Considerations of internal radiation are dealt with in paragraphs 11 and 12 of this appendix. The conditions given in the Code are such that the doses received from any one patient are unlikely to exceed acceptable amounts and it is considered that the chance of any member of the public becoming closely involved with more than one patient is very small indeed. In these circumstances the doses received will be but a small fraction of the permissible doses that may be accumulated over a period of years by individual members of the public.

**3** As regards the drivers of ambulances, their assistants, and members of the hospital car service who may be required to convey patients during treatment with radioactive substances from treatment centres, calculations have shown that it is extremely unlikely that the doses recommended for 'other persons' (see Section 1.2.1.i.b and Appendix B) will be exceeded. If, however, in exceptional circumstances there is a possibility of higher doses being received, it is the responsibility of the Radiological Protection Adviser to advise on the precautions to be adopted.

### Maximum activities of various radionuclides for patients permitted to leave hospital

**4** Table I1 gives the maximum activities in respect of the commonest radionuclides for patients to be allowed to leave hospital by public transport or who are conveyed by other means. Reference may be made to the National Radiological Protection Board about corresponding activities for radionuclides not included in Table I1.

Table I1 refers to patients in whose tissues implantations of short half-life sealed sources have been made or to whom short half-life sealed sources have been externally applied or to whom unsealed radioactive substances have been internally administered.

**Table I1**  
**MAXIMUM ACTIVITIES OF RADIONUCLIDES FOR PATIENTS**  
**PERMITTED TO LEAVE HOSPITAL**

Radionuclide	Travel by public transport	Travel by other than public transport
Iodine-131	15 mCi	30 mCi
Yttrium-90 or Gold-198 (sealed or colloidal)	30 mCi	60 mCi
Phosphorus-32	30 mCi	30 mCi

The above activities are subject to modification in the light of special circumstances (see paragraphs 5 and 12).

### **Journey Times**

**5** The recommendations regarding travel by public transport have been based on a journey time in any one vehicle of 1 hour. If it is known that a journey of substantially longer duration is involved, either the activity on leaving hospital should be limited in proportion, or the patient should travel by means other than public transport.

**6** Subsequent journeys by public transport should be limited to 1 hour. Restrictions can be removed when the activity within or on the body has fallen to one quarter of the appropriate value in column 2 of Table I1, the date on which this occurs should be given on the instruction card.

### **Conduct at home**

**7** On the basis of some simple assumptions as to the time spent at various distances from the patient by members of the family and friends, an estimate can be obtained of the doses likely to be received by these people if the patient were given no instructions as to his subsequent conduct.

**8** Based on the activities given in column 3 of Table I1, the following conclusions may be drawn from these calculations:

- i Visitors are unlikely to receive more than 30 mrads from any one of the different types of treatment.
- ii Children could receive about 1.5 to 2 rads to their eyes and about 300 mrads to their gonads from a patient treated with a superficial implant or external applicator. Much the greater part of this dose is due to the assumption that unless instructed to the contrary, the patient might play with, nurse, or fondle young children.

**9** From this it appears that there is no hazard for visitors, but that patients treated with radionuclides should not play with, nurse, or fondle children. With regard to the spouse, it seems advisable to recommend that he or she, if still of reproductive capacity should not share the same bed as the patient. Both these restrictions can be removed when the activity within or on the body has fallen to one quarter of the appropriate value given in column 2 of Table II. The date on which this occurs should be given on the instruction card but instructions regarding children and the spouse should be given verbally.

#### **Visits to places of entertainment and return to work**

**10** Patients treated with superficial implants or external applicators may feel well enough to visit places of entertainment or to return to work. It is however recommended that such visits or a return to work be deferred until the activity of the radiation source has fallen to one quarter of the value given in column 2 of Table II.

#### **Excretion of radioactive substances by the patient**

**11** Traces of any radioactive substance excreted by the patient may conceivably be taken into the body of another person living in close association with the patient, either by ingestion or inhalation, and precautions should be taken to minimize this. Urine and faeces can be disposed of via the normal drains, and it is felt that normal standards of hygiene will prevent any significant transfer from this source.

**12** In the case of a volatile material, such as iodine-131, however, it would be advisable to instruct the patient that particular care should be taken especially if a bed-pan is used. The radiotherapist or other clinician responsible for the patient leaving hospital should give consideration to the hazards which may arise as the result of the patient being incontinent (e.g. from the contamination of bed linen). Saliva may contain traces of radioactive substances which are readily transferred to the systemic circulation; in such cases it is advisable for the patient to keep crockery and cutlery for his own exclusive use until the activity within the body has fallen to one quarter of the appropriate value given in column 2 of Table II.

#### **Loss of sealed source**

**13** The loss of a sealed source such as a gold grain might constitute a hazard if it is caught up in a person's clothing or if it is picked up by a person ignorant of its nature. For example, a gold grain of activity 0.1 millicurie will deliver at 1 cm a gamma-ray dose of about 20 rads to complete decay and the beta-ray dose rate in contact with such a source will be about  $13 \text{ rad h}^{-1}$  the total beta-ray dose to

complete decay being about 1250 rads. Patients with superficial implants or external applicators of gold grains should be allowed to leave hospital only when the radiotherapist is satisfied that the nature of the treatment and the dressings are such that the risk of loss of a gold grain is remote.

**Instruction card to be given to patients on leaving a hospital during treatment with radioactive substances**

<p><b>1</b> It is important that you carry this card at all times until the date shown on page 1.</p> <p><b>2</b> If you have any difficulty or an accident occurs you should ring the hospital shown on page 1.</p>	<p style="text-align: center;"><b>RADIONUCLIDE INSTRUCTION CARD</b></p> <p>Instructions cease to apply on:—</p> <p>Patient's name</p> <p>Private address</p> <p>Patient's hospital record number</p> <p>Hospital address</p> <p>Hospital telephone No</p> <p>Hospital department and telephone No</p>
<p style="text-align: center;">4</p>	<p style="text-align: center;">1</p>

<p>Radionuclide administered:</p> <p>Activity.....on.....date</p> <p><b>SPECIAL INSTRUCTIONS</b></p> <p>(a) Public Transport</p> <p>(b) Work</p>	<p>(c) Places of entertainment</p> <p>(d) Home</p> <p>(e) Other</p> <p>Signature of doctor:</p>
<p style="text-align: center;">2</p>	<p style="text-align: center;">3</p>

## APPENDIX J

# RADIATION HAZARDS DURING THE DISPOSAL OF RADIOACTIVE CORPSES

- 1 The Radiological Protection Adviser should advise Radiological Safety Officers in hospitals for which he is responsible on the precautions to be taken in the disposal of radioactive corpses.
- 2 The Radiological Safety Officer of the hospital department in which the treatment with radionuclides was given should be consulted by those responsible for disposal of the body and for post-mortem procedures on the radiation problems that might arise.
- 3 The hazards associated with diagnostic or tracer amounts of radioactive substances are negligible, and no special precautions need be taken.
- 4 No special precautions are necessary in the direct burial, without embalming, of deceased persons who have received therapeutic doses of radionuclides.
- 5 No special precautions are necessary for the post-mortem examination outside treatment centres of the embalming of corpses containing not more than 5 millicuries colloidal yttrium-90 or gold-198, 10 millicuries phosphorus-32 or 15 millicuries iodine-131 or sealed yttrium-90 or gold-198.
- 6 Corpses containing greater activities than those specified in paragraph 5 should not normally be embalmed, but if there are special reasons for doing so in a particular case, the embalmer should first consult the hospital where the treatment was given.
- 7 The activities given in paragraph 5 are not necessarily applicable to post-mortem examinations at the treatment centre where the cases might be more frequent and the activities greater. At such centres the pathologist should, in consultation with the Radiological Safety Officer of the relevant department, familiarize himself with the radiation levels likely to be encountered and with the hazards involved. The methods employed and the precautions adopted should be chosen accordingly. Consideration should be given to the classification as designated persons of such pathologists and their assistants.
- 8 No special precautions are necessary for the cremation of corpses containing up to 30 millicuries yttrium-90, iodine-131, gold-198, or 10 millicuries phosphorus-32.

**9** Temporary implants of radionuclides should be removed from corpses before their release from hospitals.

**10** The possibility exists that a post-mortem examination might be carried out, without the knowledge of the general practitioner concerned, on a corpse having an activity greater than those specified in paragraph 5, in which circumstances the pathologist will not be aware of the presence of radioactive substances. These occurrences are likely to be exceedingly rare and the probability that any pathologist will receive sufficient numbers of such corpses as to constitute a hazard is regarded as negligible.

**11** The National Radiological Protection Board is available for consultation in cases of radionuclides other than those referred to above.

## APPENDIX K

# TRANSPORT OF RADIOACTIVE SUBSTANCES OUTSIDE HOSPITALS

**1** An outline is given in this Appendix of the regulations or conditions already in force or likely to be put forward by bodies responsible for the various modes of transport. It is emphasized that this information is presented only as a guide and that each Radiological Safety Officer who is responsible for the transport of radioactive substances outside hospitals must seek authoritative advice regarding the modes of transport he wishes to employ. The responsible Government Departments are as follows:

Road and Rail – Department of the Environment (In Northern Ireland the Ministry of Home Affairs).

Sea and Air – Department of Trade and Industry.

The British Railways Board issues its own regulations, but refers to the Secretary of State for the Environment as the competent authority for approval of Type B packaging designs, special forms of encapsulation, large source package designs, large source movements and other proposals. The transport of radioactive substances by post is subject to regulations issued by the Post Office and is prohibited except by prior arrangement. Advice in respect of all modes of transport, except by post, for the whole of the United Kingdom can be obtained from the Head of the Dangerous Goods Branch, Department of the Environment, who is responsible on behalf of the competent authorities mentioned above for most of the appropriate approval certificates.

At the time of writing regulations are in force for road<sup>11,12</sup>, rail<sup>15</sup>, sea<sup>13</sup>, and air<sup>14</sup> transport; detailed recommendations are published in the Blue Book<sup>57</sup> for sea transport and by the International Air Transport Association<sup>58</sup>. For details regarding transmission by post, reference should be made to the Post Office Guide.

**2** All United Kingdom transport regulations are based upon the International Atomic Energy Agency Transport Regulations<sup>34</sup>.

**3** To minimize the hazard to persons and to undeveloped photographic film or plates, packaging for radioactive substances must be designed to certain standards. Essentially the packages must be:

- i Not less than 10 cm for the smallest external dimension.
- ii Leak proof with respect to contents.
- iii Securely closed.
- iv Shielded to the required extent.
- v Free of external contamination.

4 For the majority of movements of radioactive substances, two standards of packaging are acceptable:

- i Type A capable of withstanding normal transport conditions and minor accidents, such as the action of shock and water, and penetration by sharp objects.
- ii Type B designed to withstand severe accident conditions including fire. When approved by the competent authority Type B packages are suitable for most modes of transport

Design features and the assessment of packaging are dealt with in detail in the International Atomic Energy Agency Transport Regulations<sup>34</sup> and in British Standard 3895<sup>42</sup>.

5 The activity that is permitted in a package is dependent upon the Transport Group of the radionuclide, its physical form and on the standard of packing employed. Tables K1 and K2 indicate the relevant details.

**Table K1**  
**MAXIMUM ACTIVITY IN A PACKAGE**

Type of Packaging	Transport Group							Special form radioactive substances
	I	II	III	IV	V	VI	VII	
A	1mCi	50mCi	3Ci	20Ci	20Ci	1,000Ci	1,000Ci	20Ci
B	20 Ci	20 Ci	200Ci	200Ci	5,000Ci	50,000Ci	50,000Ci	5,000Ci

6 The transport groups referred to in Table K1 differ from the toxicity classes given in Table 1 Section 6 of this Code. The radionuclides indicated in Section 6 are re-classified for transport purposes in Table K2 and it will be seen that they mainly fall into Groups I to IV. By 'special form' is meant a radioactive substance, regardless of transport group, which in addition to having other specified properties, is in the form of a massive non-friable solid of melting point greater than 538°C (1000°F), virtually non-soluble in water and non-reactive with both air and water, or encapsulated so as to meet conditions that are somewhat more severe than the foregoing. In order to take advantage of the increased activities in special form allowed in the two types of packaging, approval of the form of encapsulation by the competent authority is required.

7 The external dose rate from packages is subject to limitations which enable three categories of package to be defined, regardless of whether they are of Type A or Type B as described previously.

**Category I:** WHITE label packages where the surface dose rate does not exceed 0.5 mrem h<sup>-1</sup>.

Category II: YELLOW label packages where the surface dose rate does not exceed 10 mrem h<sup>-1</sup> and the dose rate at 1 metre from the centre does not exceed 0.5 mrem h<sup>-1</sup>.

Category III: YELLOW label packages where the surface dose rate does not exceed 200 mrem h<sup>-1</sup> and the dose rate at 1 metre from the centre does not exceed 10 mrem h<sup>-1</sup>.

8 In regard to Category II and III YELLOW packages only, the total number which may be transported or stored together is limited by a number on the label of each package called 'transport index' which represents the dose rate in millirems per hour at 1 metre from the centre of the package (for certain packages of fissile materials the number has a different significance). The transport index number will need to be written on the labels. Tables showing the distances by which radioactive packages are to be segregated from persons and undeveloped film are given in the appropriate regulations or codes of practice: the distances relate to the total transport indices of the packages stacked together. In general, a vehicle will be limited to a total transport index of 50, which may be exceeded only in special circumstances. In the type of vehicle referred to in paragraph 14 of this appendix the total transport index may be limited to less than 50.

9 Low activities of radionuclides are exempted from most of the packaging and labelling requirements of the Regulations<sup>11</sup> subject to certain conditions, for example, that the dose rate at the surface of the package does not exceed 0.5 mrem h<sup>-1</sup>. The maximum activities for exemption are given in Table K3.

Table K2

CLASSIFICATION OF RADIONUCLIDES USED IN HOSPITALS IN THE UNITED KINGDOM  
INTO GROUPS FOR TRANSPORT PURPOSES

a For the purpose of transport regulations radioactive substances are divided into seven groups, and individual radionuclides are assigned to a certain group, these are not to be confused with the toxicity classification classes in Appendix L.

Group I	Group II	Group III	Group IV
Radium-226	Strontium-90 Lead-210 Radium-224 (Thorium-X)	Sodium-22 Chlorine-36 Potassium-43 Cobalt-56 Cobalt-60 Iodine-125 Iodine-131 Caesium-137 Thulium-170 Tantalum-182 Iridium-192 Thallium-204 Krypton-85 (compressed) Xenon-133 (compressed)	Hydrogen-3 (as tritiated water or other compounds) Carbon-14 Fluorine-18 Sodium-24 Phosphorus-32 Sulphur-35 Chlorine-38 Potassium-42 Calcium-45 Calcium-47 Scandium-47 Chromium-51 Iron-55 Iron-59 Cobalt-57 Cobalt-58 Copper-64 Arsenic-74 Arsenic-76 Selenium-75 Bromine-82 Rubidium-86 Strontium-85 Yttrium-90 Molybdenum-99 Technetium-99m Indium-113m Tin-113 Tellurium-132 Iodine-132 Caesium-131 Promethium-147 Gold-198 Mercury-197 Mercury-203 Bismuth-206

b Apart from a few radionuclides such as Krypton-85 (uncompressed) and Xenon-133 (uncompressed), both assigned to Group VI, radionuclides in groups V, VI and VII are unlikely to be of interest to users of this Code of Practice.

c Certain radionuclides used in hospitals are not at present classified in the IAEA Regulations<sup>33</sup>. They are: Carbon-11, Nitrogen-13, Oxygen-15, Iron-52, Gallium-67, Gallium-68, Germanium-68, Rubidium-81, Strontium-87m, Yttrium-87, Iodine-123 and Caesium-129. However, in accordance with the formula given in the Regulations<sup>33</sup>, these can be allocated to group III.

**Table K3**  
**MAXIMUM ACTIVITIES FOR EXEMPT SUBSTANCES AND INSTRUMENTS**

Transport Group	Exempt Substances	Exempt Instruments†	
	per package	per instrument	per package
I	0.01 mCi	0.1 mCi	1 mCi
II	0.1 mCi	1 mCi	50 mCi
III	1 mCi	10 mCi	3 Ci
IV	1 mCi*	50 mCi	3 Ci
V	1 mCi	1 Ci	1 Ci
VI	1 mCi	1 Ci	1 Ci
VII	25 Ci	25 Ci	200 Ci
Special Form	1 mCi	50 mCi	20 Ci

\*For tritiated water there is no limit for concentrations not greater than 0.5 mCi per ml.

†For example, radiation monitors with built-in check sources.

**10** Large sources, that is, with activity per package in excess of the Type B limits mentioned in Table K1, require special approval for movement on the public highway. (See paragraph 1).

**11** The contamination by loose radioactive substances of the outer surfaces of packages is limited to not more than  $10^{-5} \mu\text{Ci cm}^{-2}$  for alpha emitters and  $10^{-4} \mu\text{Ci cm}^{-2}$  for beta or gamma emitters. These values apply to averages obtained over an area of  $300 \text{ cm}^2$ .

**12** Packages containing radioactive substances may be conveyed by passenger or merchandise train but only in accordance with the relevant regulations. They are prohibited on the London Underground System and in public service vehicles (buses, coaches, trolley-buses or trams).

**13** For road transport there will need to be an appropriate notice in the driver's cab, a consignment note, and consignor's certificate, and measures taken for limiting the dose rate to the driver; it will also be necessary to take steps to minimize the possibility of loss or pilfering and to make arrangements for the notification of participating organizations in the event of any untoward occurrence (NAIR Scheme).

**14** Subject to the conditions regarding packaging and labelling and a special limitation on numbers of packages and total transport index, it is permissible to transport radioactive substances in private cars, estate cars, taxis and similar vehicles constructed for the carriage of passengers and their effects, provided they are accompanied by a person who is aware of the precautions to be adopted; also in ambulances, provided they are accompanied by a person nominated by a Radiological Safety Officer of the hospital. The

Radiological Safety Officer must satisfy himself that the doses likely to be received by all concerned are at acceptable levels and that satisfactory arrangements have been made to summon and supply assistance in the event of an accident or other emergency. It is anticipated that no difficulties will arise concerning the provision of vehicle insurance. However, since insurance contracts are contracts of the utmost good faith, the insurer must be fully informed; changes in the terms may affect the premiums.

**15** If circumstances arise which make it difficult to comply with all the regulations or conditions pertaining to a particular form of transport, there is generally provision for making special arrangements on application to the Head of the Dangerous Goods Branch, Department of the Environment. This is not to be regarded as a means of avoiding compliance with the normal conditions, and the special arrangements will be aimed at ensuring that the movement is as safe as if it had complied with the normal conditions in every respect.

## APPENDIX L

# CLASSIFICATION OF RADIONUCLIDES ACCORDING TO RELATIVE RADIOTOXICITY PER UNIT ACTIVITY

In the list 'm' means the metastable state.

### High Toxicity (Class 1)

RADIONUCLIDE	MASS NUMBER	SYMBOL
Lead	210	Pb
Polonium	210	Po
Radium	223	Ra
Radium	226	Ra
Radium	228	Ra
Actinium	227	Ac
Thorium	227	Th
Thorium	228	Th
Thorium	230	Th
Protoactinium	231	Pa
Uranium	230	U
Uranium	232	U
Uranium	233	U
Uranium	234	U
Neptunium	237	Np
Plutonium	238	Pu
Plutonium	239	Pu
Plutonium	240	Pu
Plutonium	241	Pu
Plutonium	242	Pu
Americium	241	Am
Americium	243	Am
Curium	242	Cm
Curium	243	Cm
Curium	244	Cm
Curium	245	Cm
Curium	246	Cm
Californium	249	Cf
Californium	250	Cf
Californium	252	Cf

### Medium Toxicity: Upper Sub-Group A (Class 2)

RADIONUCLIDE	MASS NUMBER	SYMBOL
Sodium	22	Na
Chlorine	36	Cl
Calcium	45	Ca
Scandium	46	Sc
Manganese	54	Mn
Cobalt	60	Co
Strontium	89	Sr
Strontium	90	Sr
Yttrium	91	Y
Zirconium	95	Zr
Ruthenium	106	Ru

RADIOMUCLEIDE	MASS NUMBER	SYMBOL
Silver	110m	Ag
Cadmium	115m	Cd
Indium	114m	In
Antimony	124	Sb
Antimony	125	Sb
Tellurium	127m	Te
Tellurium	129m	Te
Iodine	126	I
Iodine	131	I
Iodine	133	I
Caesium	134	Cs
Caesium	137	Cs
Barium	140	Ba
Cerium	144	Ce
Europium (half-life—13 years)	152	Eu
Europium	154	Eu
Terbium	160	Tb
Thulium	170	Tm
Hafnium	181	Hf
Tantalum	182	Ta
Iridium	192	Ir
Thallium	204	Tl
Lead	212	Pb
Bismuth	207	Bi
Bismuth	210	Bi
Astatine	211	At
Radium	224	Ra
Actinium	228	Ac
Thorium	234	Th
Protoactinium	230	Pa
Uranium	236	U
Berkelium	249	Bk

### Medium Toxicity: Lower Sub-Group B (Class 3)

RADIOMUCLEIDE	MASS NUMBER	SYMBOL
Beryllium	7	Be
Carbon	14	C
Fluorine	18	F
Sodium	24	Na
Silicon	31	Si
Phosphorus	32	P
Sulphur	35	S
Chlorine	38	Cl
Argon	41	A
Potassium	42	K
Calcium	47	Ca
Scandium	47	Sc
Scandium	48	Sc
Vanadium	48	V
Chromium	51	Cr
Manganese	52	Mn
Manganese	56	Mn
Iron	55	Fe
Iron	59	Fe
Cobalt	57	Co
Cobalt	58	Co
Nickel	63	Ni
Nickel	65	Ni
Copper	64	Cu
Zinc	65	Zn

RADIOMUCLIDE	MASS NUMBER	SYMBOL
Zinc	69m	Zn
Gallium	72	Ga
Arsenic	73	As
Arsenic	74	As
Arsenic	76	As
Arsenic	77	As
Selenium	75	Se
Bromine	82	Br
Krypton	85m	Kr
Krypton	87	Kr
Rubidium	86	Rb
Strontium	85	Sr
Strontium	91	Sr
Strontium	92	Sr
Yttrium	90	Y
Yttrium	92	Y
Yttrium	93	Y
Zirconium	97	Zr
Niobium	93m	Nb
Niobium	95	Nb
Molybdenum	99	Mo
Technetium	96	Tc
Technetium	97m	Tc
Technetium	97	Tc
Technetium	99	Tc
Ruthenium	97	Ru
Ruthenium	103	Ru
Ruthenium	105	Ru
Rhodium	105	Rh
Palladium	103	Pd
Palladium	109	Pd
Silver	105	Ag
Silver	111	Ag
Cadmium	109	Cd
Cadmium	115	Cd
Indium	115m	In
Tin	113	Sn
Tin	125	Sn
Antimony	122	Sb
Tellurium	125m	Te
Tellurium	127	Te
Tellurium	129	Te
Tellurium	131m	Te
Tellurium	132	Te
Iodine	132	I
Iodine	134	I
Iodine	135	I
Xenon	135	Xe
Caesium	131	Cs
Caesium	136	Cs
Barium	131	Ba
Lanthanum	140	La
Cerium	141	Ce
Cerium	143	Ce
Praseodymium	142	Pr
Praseodymium	143	Pr
Neodymium	147	Nd
Neodymium	149	Nd
Promethium	147	Pm
Promethium	149	Pm
Samarium	151	Sm

RADIOMUCLIDE	MASS NUMBER	SYMBOL
Samarium	153	Sm
Europium (half-life—9.2 hours)	152	Eu
Europium	155	Eu
Gadolinium	153	Gd
Gadolinium	159	Gd
Dysprosium	165	Dy
Dysprosium	166	Dy
Holmium	166	Ho
Erbium	169	Er
Erbium	171	Er
Thulium	171	Tm
Ytterbium	175	Yb
Lutecium	177	Lu
Tungsten	181	W
Tungsten	185	W
Tungsten	187	W
Rhenium	183	Re
Rhenium	186	Re
Rhenium	188	Re
Osmium	185	Os
Osmium	191	Os
Osmium	193	Os
Iridium	190	Ir
Iridium	194	Ir
Platinum	191	Pt
Platinum	193	Pt
Platinum	197	Pt
Gold	196	Au
Gold	198	Au
Gold	199	Au
Mercury	197	Hg
Mercury	197m	Hg
Mercury	203	Hg
Thallium	200	Tl
Thallium	201	Tl
Thallium	202	Tl
Lead	203	Pb
Bismuth	206	Bi
Bismuth	212	Bi
Radon	220	Rn
Radon	222	Rn
Thorium	231	Th
Protoactinium	233	Pa
Neptunium	239	Np

#### Low Toxicity (Class 4)

RADIOMUCLIDE	MASS NUMBER	SYMBOL
Hydrogen	3	H
Argon	37	A
Cobalt	58m	Co
Nickel	59	Ni
Zinc	69	Zn
Germanium	71	Ge
Krypton	85	Kr
Rubidium	87	Rb
Strontium	85m	Sr
Yttrium	91m	Y
Zirconium	93	Zr
Niobium	97	Nb
Technetium	96m	Tc

RADIONUCLIDE	MASS NUMBER	SYMBOL
Technetium	99m	Tc
Rhodium	103m	Rh
Indium	113m	In
Indium	115	In
Iodine	129	I
Xenon	131m	Xe
Xenon	133	Xe
Caesium	134m	Cs
Caesium	135	Cs
Neodymium	144	Nd
Samarium	147	Sm
Rhenium	187	Re
Osmium	191m	Os
Platinum	193m	Pt
Platinum	197m	Pt
Thorium	232	Th
Natural Thorium		Th-Nat
Uranium	235	U
Uranium	238	U
Natural Uranium		U-Nat
Depleted Uranium		U-Dep
Enriched Uranium		U-Enr

**Note:** This classification derives from the Technical Reports Series No. 15 -A Basic Toxicity Classification of Radionuclides, IAEA Vienna (1963). It does not include 17 radionuclides which are being used in the U.K. On the basis of National Radiological Protection Board calculations of mpc air for these 17, their classification will be:

RADIONUCLIDE	MASS NUMBER	SYMBOL	CLASS
Cobalt	56	Co	2
Germanium	68	Ge	2
Iodine	124	I	2
Iodine	125	I	2
Potassium	43	K	3
Iron	52	Fe	3
Gallium	67	Ga	3
Rubidium	81	Rb	3
Yttrium	87	Y	3
Iodine	123	I	3
Iodine	130	I	3
Caesium	129	Cs	3
Carbon	11	C	4
Nitrogen	13	N	4
Oxygen	15	O	4
Gallium	68	Ga	4
Strontium	87m	Sr	4

## APPENDIX M

# DEFINITIONS OF TERMS

**Active area:** area in which the derived working limits for surface contamination specified for categories C and D of Table D1, are exceeded or are liable to be exceeded under normal operating conditions.

**Adequate protection:** protection which is intended to ensure that the doses given in tables B1 and B2 (depending on the category of persons exposed) are not exceeded. In the provision of adequate protection, cognizance will need to be taken of all situations in which occupational exposure of the worker to radiation could occur.

**Controlling Authority:** body or person or persons ultimately responsible for the control of the establishment or the work which is subject to the provisions of this Code. In the case of NHS hospitals, the Controlling Authority is the Board of Governors or Hospital Management Committee (in Scotland, the Board of Management).

**Derived working limit:** a limit derived from the dose limits recommended by the International Commission on Radiological Protection in such a way that compliance with it implies virtual certainty of compliance with the relevant dose limits.

**Occupancy factor:** factor by which the work-load should be multiplied to allow for the type and extent of occupancy of the area in question. This is one of the factors that may be taken into consideration in designing the shielding requirements for the area. (See also use factor).

**Radioactive substance:** strictly, any substance consisting of or containing a radionuclide; however, since even ostensibly stable substances contain trace amounts of radioactive nuclides, a limit has been generally agreed below which the radioactivity can be ignored for most pur-

poses. This limit is set such that a substance is considered to be radioactive if it consists of or contains any radioactive chemical element whose specific activity exceeds 0.002 of a microcurie of parent radioactive chemical element per gramme of substance. (Note: This definition is not in the same terms as that used in the Radioactive Substances Act, 1960<sup>2</sup>, for the purposes of disposal of radioactive waste).

**Significant:**

significant is used in the Code in a number of contexts. It is intended to indicate levels of dose which, either because of their unexpectedness or because of repetition of such doses, might result in irradiation at about one third or more of a maximum permissible value for a particular class of person. The cause of a single unexpected dose of such a magnitude should be the subject of an investigation.

**Use factor:**

fraction of the work-load during which the useful beam is directed towards the area in question. This is one of the factors that may be taken into consideration in designing the shielding requirements for the area. (See also occupancy factor.)

**Work-load:**

a measure in appropriate units of the amount of use of radiation equipment, e.g., it might be expressed in mA min per week for X-ray sources and rontgens per week at 1 metre from the source for gamma-ray sources.

## APPENDIX N

# RADIATION AND CONTAMINATION MONITORING INSTRUMENTS

**1** Information on manufacturers of monitoring instruments in the UK may be obtained from:

- i Scientific Instrument Manufacturers' Association  
Instrument Enquiry Service  
Scientific Instruments Research Association  
South Hill  
Elmstead Woods  
Chislehurst  
Kent.  
BR 7 5EH  
Telephone No. 01-467 2636

**2** Advice on the selection of suitable instruments for any particular monitoring purposes may be obtained from:

- i National Radiological Protection Board  
Headquarters and Southern Centre  
Harwell  
Didcot  
Berkshire  
Telephone No. 023-583 545
- ii National Radiological Protection Board  
South Eastern Centre  
Clifton Avenue  
Belmont  
Sutton  
Surrey  
Telephone No. 01-643 5441
- iii National Radiological Protection Board  
Northern Centre  
29 Clarendon Road  
Leeds  
LS2 9PD  
Telephone No. 0532-40931
- iv National Radiological Protection Board  
Scottish Centre  
9 West Graham Street  
Glasgow  
G4 9LF  
Telephone No. 041-332 6061

## APPENDIX O

# REFERENCES

### Acts and Regulations

- 1 *Radioactive Substances Act*, 1948, HMSO, London
- 2 *Radioactive Substances Act*, 1960, HMSO, London
- 3 *The Ionising Radiations (Sealed Sources) Regulations*, 1969 (S.I. 1969 No. 808), HMSO, London
- 4 *The Ionising Radiations (Unsealed Radioactive Substances) Regulations*, 1968 (S.I. 1968 No. 780), HMSO, London
- 5 *The Radioactive Substances (Hospitals' Waste) Exemption Order*, 1963 (S.I. 1963 No. 1833), HMSO, London
- 6 *The Radioactive Substances (Hospitals' Waste) Exemption (Scotland) Order*, 1963 (S.I. 1963 No. 1879 S96), HMSO, Edinburgh
- 7 *The Radioactive Substances (Hospitals' Waste) Exemption Order (Northern Ireland)*, 1963 (S.R. & O. (N.I.) 1963 No. 217), HMSO, Belfast
- 8 *The Radioactive Substances (Thorium-X) Exemption Order*, 1963 (S.I. 1963 No. 1834) HMSO, London
- 9 *The Radioactive Substances (Thorium-X) Exemption (Scotland) Order*, 1963 (S.I. 1963 No. 1880 S97), HMSO, Edinburgh
- 10 *The Radioactive Substances (Thorium-X) Exemption Order (Northern Ireland)*, 1963 (S.R. & O. (N.I.) 1963 No. 221), HMSO, Belfast
- 11 *Radioactive Substances (Carriage by Road) (Great Britain) Regulations*, 1970 (S.I. 1970 No. 1826), HMSO, London
- 12 *Radioactive Substances (Road Transport Workers) (Great Britain) Regulations*, 1970 (S.I. 1970 No. 1827), HMSO, London
- 13 *The Merchant Shipping (Dangerous Goods) Rules*, 1965 (S.I. 1965 No. 1067), amended by S.I. 1968 No. 382, HMSO, London
- 14 *The Air Navigation Order*, 1966 (S.I. 1966 No. 1184), HMSO, London
- 15 *Dangerous Goods by Freight Train and by Passenger Train or by Similar Service. List of Dangerous Goods & Conditions of Acceptance*, BR 22426 Revised Nov. 1966, British Railways Board

## International Commission on Radiological Protection Publications:

- 16 *ICRP Publication 2 – Report of Committee 2 on Permissible Dose for Internal Radiation*, 1959, Pergamon Press
- 17 *ICRP Publication 3 – Report of Committee 3 on Protection against X-rays up to Energies of 3 MeV and Beta and Gamma Rays from Sealed Sources*, 1960, Pergamon Press
- 18 *ICRP Publication 4 – Report of Committee 4 on Protection against Electromagnetic Radiation above 3 MeV and Electrons, Neutrons and Protons*, 1964, Pergamon Press
- 19 *ICRP Publication 5 – Report of Committee 5 on the Handling and Disposal of Radioactive Materials in Hospitals and Medical Research Establishments*, 1964, Pergamon Press
- 20 *ICRP Publication 6 – The Recommendations of the International Commission on Radiological Protection (as amended 1959 and revised 1962)*, 1964, Pergamon Press
- 21 *ICRP Publication 7 – Principles of Environmental Monitoring related to the Handling of Radioactive Materials. A Report by Committee 4 of the International Commission on Radiological Protection*, 1965, Pergamon Press
- 22 *ICRP Publication 8 – The Evaluation of Risks from Radiation. A report prepared for Committee 1 of the International Commission on Radiological Protection*, 1966, Pergamon Press
- 23 *ICRP Publication 9 – Recommendations of the International Commission on Radiological Protection*, 1966, Pergamon Press
- 24 *ICRP Publication 10 – Report of Committee 4 on Evaluation of Radiation Doses to Body Tissues from Internal Contamination due to Occupational Exposure*, 1968, Pergamon Press
- 25 *ICRP Publication 11 – A Review of the Radiosensitivity of the Tissues in Bone. A report prepared for Committees 1 and 2 of the International Commission on Radiological Protection*, 1968, Pergamon Press
- 26 *ICRP Publication 12 – General Principles of Monitoring for Radiation Protection of Workers. A Report by Committee 4 of the International Commission on Radiological Protection*, 1969, Pergamon Press
- 27 *ICRP Publication 14 – Radiosensitivity and Spatial Distribution of Dose. Reports prepared by two task groups of Committee 1 of the International Commission on Radiological Protection*, 1969, Pergamon Press

28 *ICRP Publication 15 – Protection against Ionising Radiations from External Sources. A Report by Committee 3 of the International Commission on Radiological Protection, 1970, Pergamon Press*

29 *ICRP Publication 16 – Protection of the Patient in X-Ray Diagnosis. A Report prepared for Committee 3 of the International Commission on Radiological Protection, 1970, Pergamon Press*

30 *ICRP Publication 17 – Protection of the Patient in Radionuclide Investigations. A Report prepared for the International Commission on Radiological Protection, 1971, Pergamon Press*

#### **International Atomic Energy Agency Publications Safety Series**

31 *No. 1 Safe Handling of Radioisotopes. First Edition with revised Appendix 1, 1962, IAEA, Vienna (under revision)*

32 *No. 2 Safe Handling of Radioisotopes. Health Physics Addendum, 1960, IAEA, Vienna*

33 *No. 3 Safe Handling of Radioisotopes. Medical Addendum, 1960, IAEA, Vienna*

34 *No. 6 Regulations for the Safe Transport of Radioactive Materials, 1967 Edition, 1967, IAEA, Vienna*

35 *No. 7 Regulations for the Safe Transport of Radioactive Materials, Notes on Certain Aspects of the Regulations, 1961, IAEA, Vienna*

#### **Technical Report Series**

36 *No. 15 A Basic Toxicity Classification of Radionuclides, 1963, IAEA, Vienna*

#### **British Standards**

37 BS 2606: 1955 *X-ray protective gloves for medical purposes up to 150 kV peak*

38 BS 2660: 1955 *Colours for building and decorative paints*

39 BS 3202: 1959 *Recommendations on laboratory furniture and fittings*

40 BS 3783: 1964 *X-ray lead-rubber protective aprons for personal use*

41 BS 381C: 1964 *Colours for specific purposes*

<b>42</b>	<b>BS 3895:</b>	<i>Methods for the assessment of packaging for the transport of radioactive materials</i>
	3895 Pt 1: 1965	<i>Materials other than large radioactive sources and fissile materials</i>
	3895 Pt 2: 1968	<i>Fissile materials and large sources</i>
<b>43</b>	<b>BS 3510: 1968</b>	<i>A basic symbol to denote the actual or potential presence of ionising radiation</i>
<b>44</b>	<b>BS 4247:</b>	<i>The assessment of surface materials for use in radioactive areas</i>
	4247 Pt 1: 1967	<i>Method of test for ease of decontamination</i>
	4247 Pt 2: 1969	<i>Guide to the selection of materials</i>

Available from British Standards Institution, British Standards House, 2 Park Street, London, W1Y 4AA

### Other Publications

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